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...mary Tenorrhaphies and Tendon Grafting Procedures in Hand Injuries
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... Experimental and Clinical Study of Vascular Spasm
Edward H. Simmons

...servation of Rectum in Familial Polyposis of the Colon and Rectum
Sherman T. Coleman and Charles Eckert

...havior and Fate of Ileal Segments Interposed in the Left Colon
Jack A. Thompson and Robert N. Watman

...ncer of the Breast, 1661 Patients
Robert C. Hickey, H. Dabney Kerr, Robert T. Tidrick, Higdon B. Elkins, and Edward E. Wieben

...sults of Pelvic Exenteration
Eugene M. Bricker, Harvey R. Butcher, and Alan McAfee

...dical Surgery in Advanced Carcinoma of Intra-Abdominal Organs
John Van Prohaska, Thomas S. Nelsen, and Shirl O. Evans

OCTOBER 1956

VOLUME 73 **NUMBER 4**

Complete Contents on First Inside Page

From Thompson and Watman, p. 645

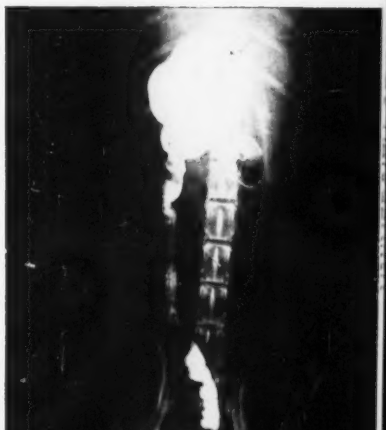

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TABLE OF CONTENTS

VOLUME 73 OCTOBER 1956 NUMBER 4

ORIGINAL ARTICLES

Papers Read at Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 23, 1956 (Concluded)

PAGE

Spasm of the Common Duct Producing Pain After Sphincterotomy 547
Waltman Walters, M.D., Rochester, Minn.

Tight Filum Terminale 556
Peter Hywelris Jones, M.R.C.S., and J. Grafton Love, M.D., Rochester, Minn.

Arteriovenous Fistulae and Arterial Aneurysms of the Pulmonary Arterial Tree 567
Rodman E. Taber, M.D., and J. L. Ehrenhaft, M.D., Iowa City

Surgical Management of the Complications of Reflux Esophagitis 578
F. Henry Ellis Jr., M.D.; Howard A. Andersen, M.D., and O. Theron Clagett, M.D., Rochester, Minn.

Richter's Hernia 590
Capt. Robert W. Gillespie (MC), U. S. Army; Wayne W. Glas, M.D.; George H. Mertz, M.D., Eloise, Mich., and Merle M. Musselman, M.D., Omaha

Inguinal Hernia in Children 595
C. Barber Mueller, M.D., and George Rader, M.D., St. Louis

Choledochoduodenal Fistula Complicating Duodenal Ulcer 598
Vernon Z. Hutchings, M.D.; James R. Wheeler, M.D., and Charles B. Puestow, M.D., Hines, Ill.

Observations on Venous Thrombosis 606
John McLachlin, M.D., F.R.C.S.(C), F.A.C.S., and J. C. Paterson, M.D., London, Ont., Canada

Primary Tenorrhaphies and Tendon Grafting Procedures in Hand Injuries 609
Joseph L. Posch, M.D., Detroit

An Experimental and Clinical Study of Vascular Spasm 625
Edward H. Simmons, M.D., B.Sc. (Med.), F.R.C.S.(C), M.S. (Tor.), Toronto, Ont., Canada

Preservation of Rectum in Familial Polyposis of the Colon and Rectum 635
Sherman T. Coleman, M.D., and Charles Eckert, M.D., St. Louis

Behavior and Fate of Ileal Segments Interposed in the Left Colon 645
Jack A. Thompson, M.D., Atlanta, and Robert N. Watman, M.D., Columbus, Ohio

Cancer of the Breast, 1661 Patients 654
Robert C. Hickey, M.D., Iowa City; H. Dabney Kerr, M.D., St. Michaels, Md.; Robert T. Tidrick, M.D.; Higdon B. Elkins, M.D., and Edward E. Wieben, A.B., Iowa City

Results of Pelvic Exenteration 661
Eugene M. Bricker, M.D.; Harvey R. Butcher, M.D., and Alan McAfee, M.D., St. Louis

Radical Surgery in Advanced Carcinoma of Intra-Abdominal Organs 671
John Van Prohaska, M.D.; Thomas S. Nelsen, M.D., and Shirl O. Evans, M.D., Chicago

Intestinal Injuries Following Irradiation of Pelvic Viscera for Malignancy 682
William Requarth, M.D., and Stuart Roberts, M.D., Decatur, Ill.

Innervation of the Sphincter of Oddi in the Dog 689
Philip F. Partington, M.D.; James C. Jones, M.D., and G. F. Johnson, M.D., Cleveland

The Diagnosis of Postcholecystectomy Biliary Tract Stones 694
M. A. Block, M.D.; B. E. Brush, M.D.; J. L. Ponka, M.D., and R. J. Priest, M.D., Detroit

Experimental Chronic Pancreatitis 701
Charles N. Floyd, M.D., and William M. Christophersen, M.D., Louisville, Ky.

Postoperative Pancreatitis 710
E. Thomas Boles Jr., M.D., Columbus, Ohio

Pseudocysts of the Pancreas 719
Robert L. Bradley, M.D., and Michael M. Klein, M.D., Huntington, W. Va.

Ruptured Aneurysm of Abdominal Aorta in an Eighty-Five-Year-Old Man 729
J. Herman Mahaffey, M.D., Louisville, Ky.

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VOLUME 73 — OCTOBER 1956 — NUMBER 4

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A.M.A. Archives OF SURGERY

Spasm of the Common Duct Producing Pain After Sphincterotomy

WALTMAN WALTERS, M.D., Rochester, Minn.

Neither sphincterotomy nor choledochoenterostomy has solved the problem presented by the patient who after cholecystectomy continues to have attacks of pain in the right upper quadrant which simulate biliary colic. In a paper on postcholecystectomy dyskinesia[1] I elaborated on the possible and also on some probable causes of such attacks of pain. From among the various possibilities definite evidence can be presented that one, namely inflammatory lesions in the biliary tract with associated inflammation of the sphincter of Oddi and stenosis, increases intraductal biliary pressure and produces attacks of pain. Many years ago McGowan, Butsch, and I[2] produced spasm of the sphincter of Oddi by injection of morphine or codeine. An increase in the intraductal biliary pressure resulted, and pain typical of biliary colic was produced. When 1/150 grain (0.4 mg.) of glyceryl trinitrate (nitroglycerin) was given sublingually or amyl nitrite was inhaled, intrabiliary pressure decreased immediately, and the pain was relieved.

Submitted for publication July 27, 1956.

Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 23, 1956.

Section of Surgery, Mayo Clinic and Mayo Foundation. The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

Studies of Pressure, Spasm, and Pain After Injection of a Radiopaque Substance (Umbrathor) into Common Duct

More recently, with the aid of a short-limbed T-tube or a catheter placed in the common bile duct after removal of a long-limbed T-tube, I have studied intraductal biliary pressures two to three months after transduodenal division of the sphincter of Oddi. A radiopaque thorium dioxide preparation (Umbrathor) was injected into the common duct to outline it fluoroscopically so that motility and emptying time could be studied. Pain resembling biliary colic followed the injection. Two cases in which these studies were made are reported briefly.

CASE 1.—The patient, a woman aged 43 years, gave a history of having undergone cholecystectomy elsewhere in August, 1946; no gallstones were found. From May, 1948, to March, 1949, she had attacks of severe upper abdominal pain which extended to the back; the pain was associated with nausea and vomiting. On May 3, 1949, a diagnosis was made at the Mayo Clinic of biliary dyskinesia, and on May 16, 1949, the common duct and intrahepatic ducts were explored. No stones were found, but resistance was encountered at the sphincter of Oddi; a T-tube was inserted into the common duct. On Aug. 23, 1949, the T-tube was removed. For the next two years the patient was free of attacks of pain.

The patient returned for examination in 1952. She complained of having attacks of pain similar to those before her operation. Administration of glyceryl trinitrate brought some relief.

The patient returned again in March, 1955. She stated that in January, 1955, attacks of pain had begun again, had recurred about once a week, and were getting worse and more frequent. With these attacks she had bloating, nausea, and vomiting. There was, however, no biliary obstruction. On March 21 transduodenal sphincterotomy, exploratory choledochostomy, and catheterization of the pancreatic duct were performed. No stones were found in the common duct, and there was no obstruction of the sphincter of Oddi. A small short-limbed T-tube was placed in the common duct. The patient went home to remain for six weeks while the T-tube was in place. Her general condition during this period was good. The patient returned on May 19, 1956, at which time pressure studies were carried out and the T-tube was removed.

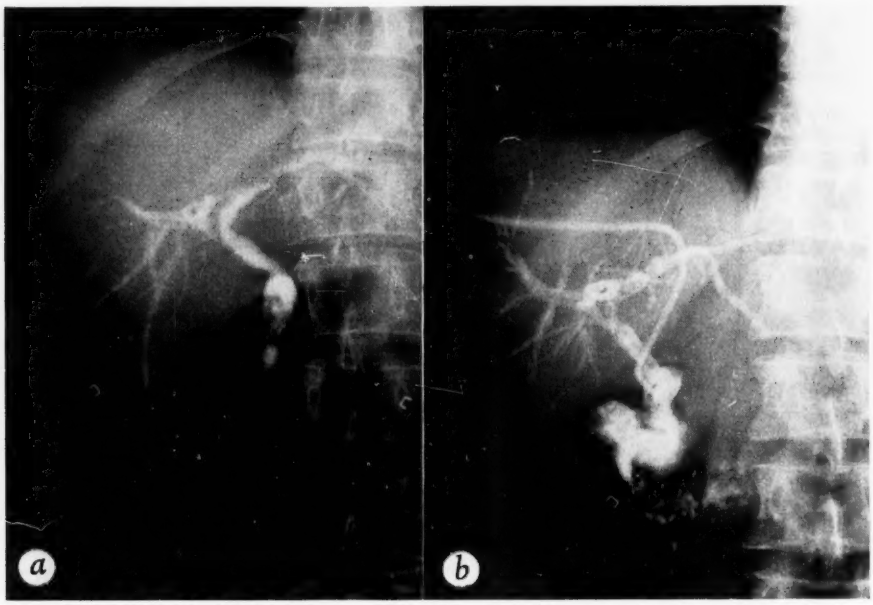

Fig. 1 (Case 1).—Cholangiograms made on May 19, 1955, two months after sphincterotomy. Thorium dioxide was injected through T-tube. (*a*) Severe spasm. (*b*) Spasm relieved by glyceryl trinitrate.

Special Studies in Case 1.—Because the patient was allergic to iodine, a radiopaque thorium dioxide substance was used instead of an iodine solution for the routine check of the size and rate of emptying of the radiopaque substance from the duct into the duodenum to determine whether it was time to remove the T-tube. After injection of the thorium through the T-tube, the patient experienced typical biliary colic and a cholangiogram showed spasm of the common duct above the site of the sphincterotomy (Fig. 1*a*). Glyceryl trinitrate administered sublingually could be seen to relieve the ductal spasm temporarily, and the pain subsided (Fig. 1*b*). The pain recurred after a short time and was partially relieved by meperidine hydrochloride, although spasm of the duct continued. Not too long afterward we were able to aspirate duodenal contents from the common duct through the short T-tube, and a study revealed no sustained intraductal pressure.

A few days later the thorium preparation was again injected into the common duct through the T-tube. Again the attack of pain occurred and intraductal pressure was increased to more than 300 mm. of water. At that time reflux of radiopaque material into the pancreatic duct was demonstrated in the roentgenogram with the ductal spasm (Fig. 2*a* and *b*). The patient's pain was epigastric and severe and

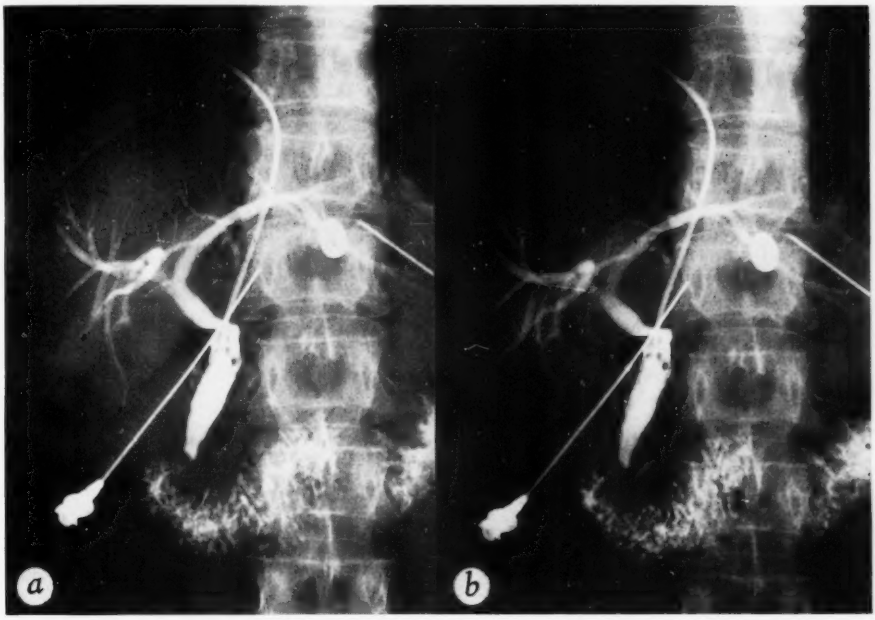

Fig. 2 (Case 1).—Cholangiograms made on May 31, 1955, after injection of 10 cc. of thorium dioxide through T-tube. (*a*) Spasm at lower end of common duct one and one-half to two minutes after injection. (*b*) Spasm five and one-half minutes after *a*. Medium has refluxed into pancreatic duct. Ductal pressure was static at 300 mm. of water.

similar to the pain that she had had before sphincterotomy. Before the thorium was injected, long hollow needles had been inserted into the left and right splanchnic regions, and when pain occurred 8 cc. of 10% solution of piperocaine (Metycaine) hydrochloride was injected into the left one to block the left splanchnic nerve. Within three seconds the patient's pain was relieved. Yet x-ray examination of the common duct at this time still showed spasm of the lower end of the duct, with retention of thorium in the common duct and in the pancreatic duct (Fig. 3*a* and *b*). The intraductal pressure was still high and static at about 200 mm. of water. Shortly afterward, a second injection of thorium dioxide was given through the T-tube (Fig. 4*a* and *b*) to increase the intraductal pressure. The epigastric pain did not return, but the patient had a feeling of fullness to the right of the incision. The right splanchnic nerve was not blocked. It is possible that the feeling of fullness was visceral in origin and due either to distention of the duct or to distention or contracture of the first part of the duodenum.

This study seems to show that spasm of the duct will cause attacks of pain simulating those caused by spasm of the sphincter of Oddi even though sphincterotomy has been done and that in such cases ductal spasm can cause reflux into the pancreatic duct. This ductal spasm and the resultant reflux may be responsible for failure of sphincterotomy to relieve attacks of pain in some cases.

In Case 2 a long T-tube was used, the lower end of which had been inserted through the divided sphincter of Oddi at the time of sphincterotomy. When the T-tube was removed three months later, the end of a catheter was immediately inserted into the lumen of the common duct through the fistulous tract, and ductal pressure and x-ray studies were made.

Case 2.—The patient, a woman 37 years old, gave a history of having had attacks of biliary

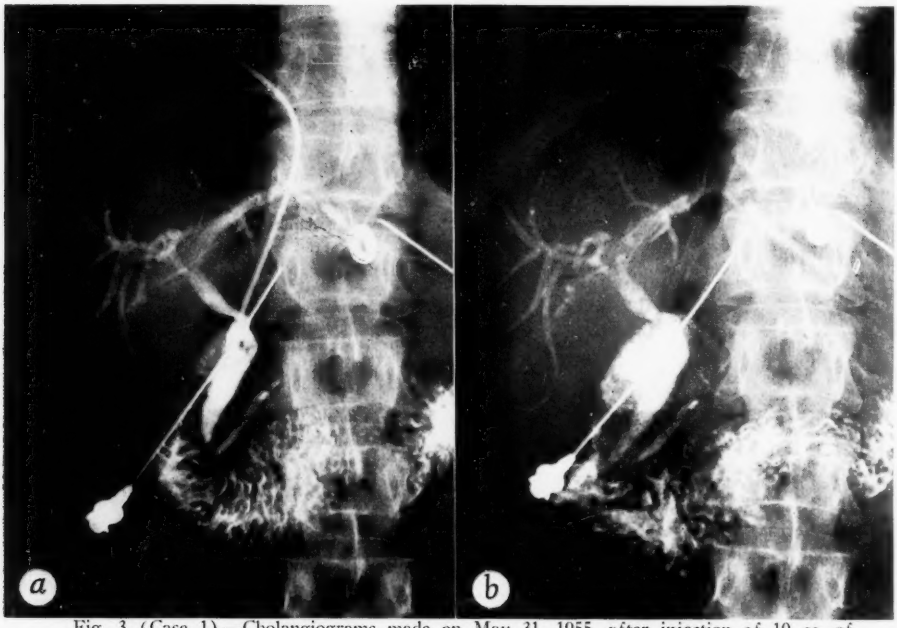

Fig. 3 (Case 1).—Cholangiograms made on May 31, 1955, after injection of 10 cc. of thorium dioxide through T-tube. (*a*) Spasm in lower end of common duct and pancreatic duct with filling of pancreatic duct three and one-half minutes after figure 2*b*. Pain had been relieved by injection of piperocaine hydrochloride. (*b*) Four minutes after *a*.

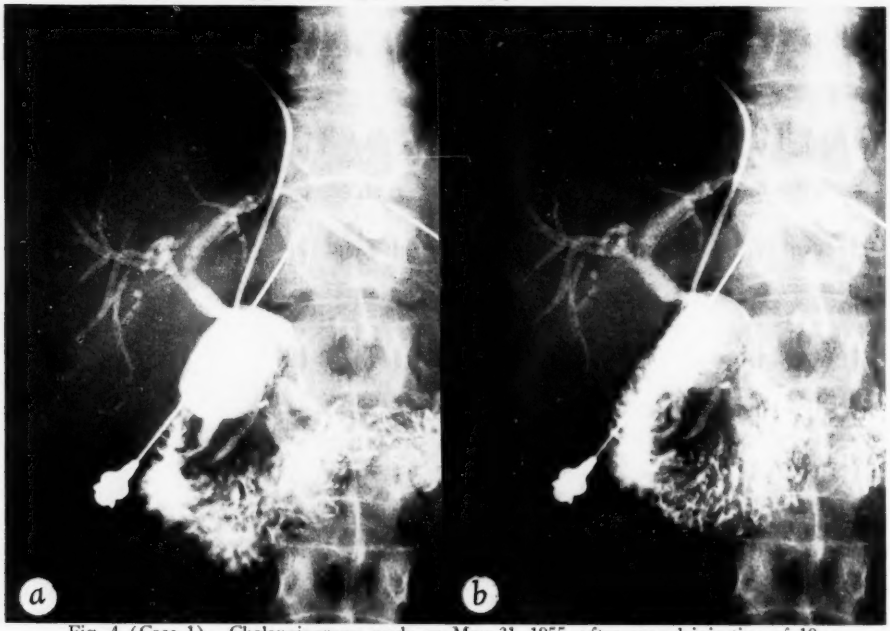

Fig. 4 (Case 1).—Cholangiograms made on May 31, 1955, after second injection of 10 cc. of thorium dioxide. Intraductal pressure was 240 to 250 mm. of water. Biliary and pancreatic ducts are outlined. (*a*) Made five minutes after Figure 3*b*. (*b*) Made five minutes after *a*.

colic intermittently for 11 years. In June, 1951, cholecystectomy was done elsewhere; small gallstones were found. Three weeks after operation, nausea, vomiting, and pain occurred. On Oct. 13, 1952, a diagnosis was made at the clinic of probable common duct stone, but the patient elected to delay exploration. When she returned in April, 1953, the stump of the cystic duct was excised and choledochostomy was performed. No stones were found in the common duct, but slight resistance was encountered at the sphincter of Oddi. A T-tube was inserted into the common duct and studies were carried out. The common duct and hepatic radicles appeared normal, and there was no evidence of calculus. On March 30, 1955, a transduodenal sphincterotomy and choledochostomy were carried out for biliary dyskinesia. There were no stones in the common duct and no obstruction at the sphincter; a long T-tube was inserted into the common duct, the lower end passing through the divided sphincter of Oddi. The patient was dismissed on April 16, 1955, with the T-tube in place. When she returned, on July 5, 1955, the T-tube was removed and the pressure studies were made.

Fig. 5 (Case 2).—T-tube has been removed and long catheter has been inserted into common duct. (*a* and *b*) Normal findings. Cholangiograms made on July 5, 1955, after injection of iodopyracet through the catheter.

was left in place for five months. When the T-tube was open, she was free of pain, and if she had pain when the tube was closed the pain was relieved when the T-tube was opened for a time. In March, 1954, the patient returned complaining of recurring pain. Right splanchnic nerve block with alcohol relieved the symptoms. She remained free of pain until July, 1954. At that time the upper abdominal pain reappeared but it was more to the left of the midline. On Aug. 11, 1954, left splanchnic block with alcohol was done, with complete relief of pain. When the patient returned on March 24, 1955, she stated that she had been free of pain until January, 1955, at which time the pain recurred with nausea. On March 28, 1955, intravenous sodium iodipamide (Cholografin)

Special Studies in Case 2.—When the long T-tube was removed, a catheter was inserted down the fistulous tract into the lumen of the common duct (Fig. 5*a*) and a cholangiogram was made (Fig. 5*b*) with the aid of iodopyracet (Diodrast), which showed a duct of normal size emptying rapidly into the duodenum. The next day thorium dioxide was injected through the catheter for a repeat cholangiogram. Pain developed, and spasm of the lower end of the common duct was demonstrated roentgenographically (Fig. 6*a*). The spasm was relieved by

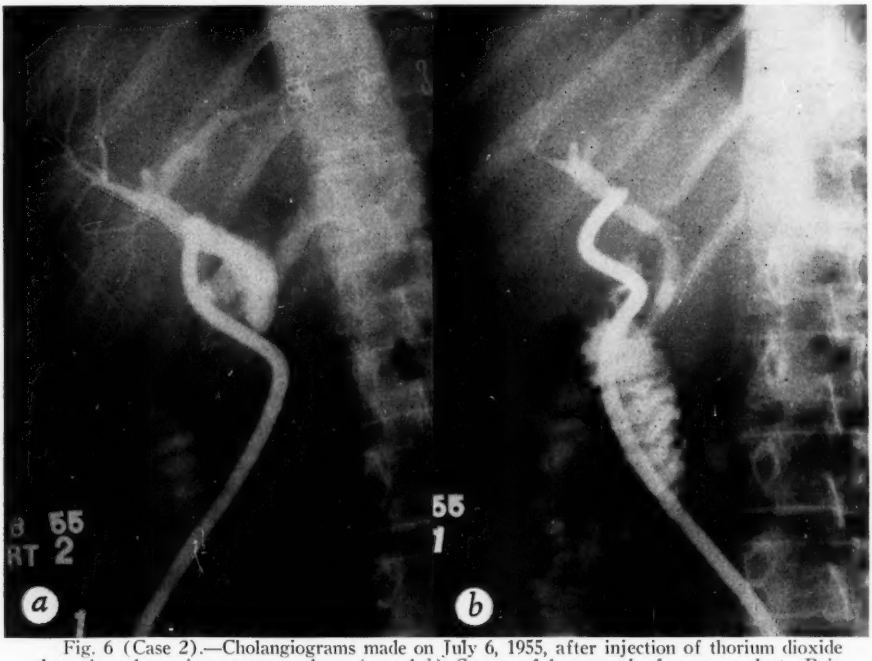

Fig. 6 (Case 2).—Cholangiograms made on July 6, 1955, after injection of thorium dioxide through catheter into common duct. (*a* and *b*) Spasm of lower end of common duct. Pain had been relieved with glyceryl trinitrate before *b*.

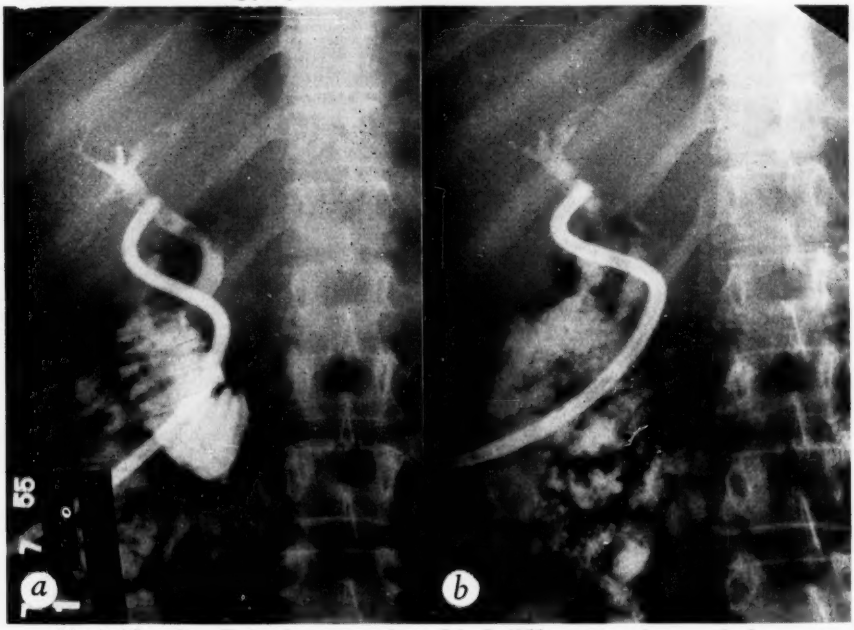

Fig. 7 (Case 2).—Cholangiograms made on July 7, 1955; spasm at lower end of common duct after injection of 10 cc. of thorium dioxide through the catheter. (*a*) Ten minutes after injection. (*b*) Thirty-five minutes after injection.

*Pressure in Common Duct in Case 2 After Injection of Thorium Dioxide Through Catheter on July 7, 1955**

Time, A.M.	Pressure, Mm. H_2O	Comment
10:50	---	Cholangiogram (thorium dioxide) 7/7/55
11:01	178	Pain in back and low in abdomen
11:05	272	
11:14	230	Still pain and nausea
11:22	228	Abdominal pain worse
11:30	230	X-ray 4 (35 minutes); glyceryl trinitrate, 0.3 mg. (Fig. 7*b*)
11:33	224	More pain in abdomen; less in back
11:35	56	Abdominal pain less
11:41	84	Glyceryl trinitrate, 0.3 mg.
11:42	82	Abdominal pain and nausea
11:47	82	Pain about gone
11:55	64	X-ray 5 (65 minutes; Fig. 8)
11:56	64	Glyceryl trinitrate, 0.3 mg.
11:58	66	Abdominal pain, nausea, headache
12:05	68	No pain
12:10	44	Study terminated

* Sphincterotomy was performed March 30, 1955.

administration of glyceryl trinitrate (Fig. 6*b*). The next day thorium dioxide was injected again, spasm of the lower end of the duct (Fig. 7*a* and *b*) and pain developed, and the intraductal pressure rose to a maximum of 272 mm. of water (Table). Pain, ductal spasm, and the increased intraductal pressure were relieved by glyceryl trinitrate. The spasm at the lower end of the duct was relieved (Fig. 8), at which time the intraductal pressure dropped to 64 mm. of water and the patient's pain ceased.

Follow-Up Data in Case 2.—On Aug. 7, 1955, the patient wrote in a letter that she continued to have attacks of abdominal pain requiring glyceryl trinitrate for relief.

At the time of her last visit, on May 30, 1956, I made a note on the record about as follows:

While this patient's T-tube was in, she was free of pain, but after the T-tube was removed she began to have infrequent and mild attacks. She considers the sphincterotomy a "tremendous success," as the attacks she is now having are much milder than those she had previously, yet sometimes she has to take 2 or 3 tablets (1/100 grain, or 0.65 mg.) of glyceryl trinitrate to relieve the pain. The relief of pain is not quite as good as it was after the alcohol splanchnic blocks.

Summary

Two cases are presented in which, two to three months after sphincterotomy and T-tube drainage of the common duct, x-ray studies of the biliary tree made after the injection of a thorium preparation (Umbrathor) showed spasm of the wall of the common duct and a tenfold increase of the intraductal pressure, with reflux of the radiopaque substance into the pancreatic duct in one case. This ductal spasm was associated

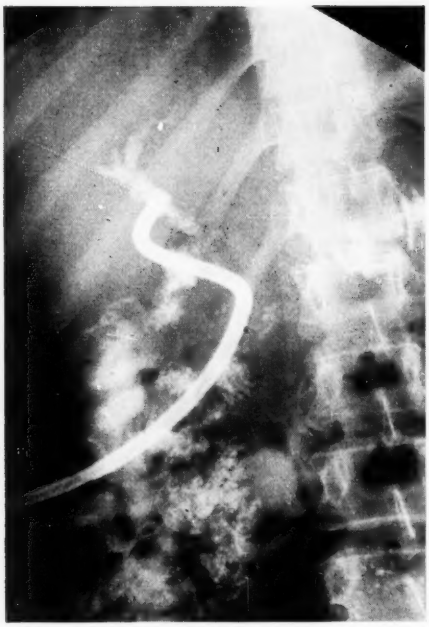

Fig. 8 (Case 2).—Cholangiogram made on July 7, 1955, sixty-five minutes after injection of thorium dioxide. Same series as Figure 7*a* and *b*.

with severe attacks of right upper abdominal pain simulating biliary colic. Glyceryl trinitrate relieved the spasm, intraductal pressure fell, the radiopaque substance entered the duodenum, and the pain was relieved. At the height of the attack, with the intraductal pressures varying from 220 to 270 mm. of water, immediate relief of the severe pain was accomplished in one case by an injection of piperocaine hydrochloride into the left splanchnic nerve area; yet the ductal pressure remained at its height and the duct was still in spasm as seen roentgenoscopically. Intraductal pressure was then increased by an additional injection of thorium dioxide; yet the pain did not reappear, although the patient had a feeling of fullness in the upper part of the abdomen. Injections were not made in the region of the right splanchnic nerve.

This study indicates that, following sphincterotomy, spasm of the common bile duct can occur and cause attacks of pain which resemble biliary colic. This pain can be relieved by blocking the left splanchnic nerves with piperocaine hydrochloride even though spasm of the duct continues and intraductal pressure remains high. In one of the cases an alcoholic block of the right splanchnic nerve was followed by complete relief of attacks of right upper abdominal pain for five months. When the pain returned it was more on the left side. It was relieved for five months by alcohol block of the left splanchnic nerve. After sphincterotomy, although the attacks of pain have diminished, they still occur.

DISCUSSION

Dr. Vernon Guynn, Chicago: I wish to thank the Central Surgical Association for the invitation to attend this meeting. And I especially wish to thank Dr. Walters for his invitation to open the discussion of his interesting paper.

Dr. John Reynolds and I have performed 42 transduodenal sphincterotomies. Although we have not followed these with any ductal pressure studies, we have been very impressed by the clinical relief of symptoms and the minimal amount of postoperative pain.

Only in those cases having complications have we noticed unusual pain. In two cases residual common duct stones were shown on cholangiograms, and after spontaneous passage of these the pain was relieved.

We have had two serious complications, both patients having severe back pain. One patient was reexplored 36 hours after his original surgery and was found to have acute hemorrhagic pancreatitis and distention of the gall bladder. This probably indicated some increased pressure in the ductal system. He recovered after a cholecystostomy and peritoneal drainage. In this case the cut edge of the duodenal mucosa was sutured to the ampullary portion of the common duct. We felt that the edema confined by these sutures resulted in blockage of the duct of Wirsung. Since then we have omitted these sutures and have had no pancreatitis, no postoperative hemorrhage, and no late stenosis. We have not used the long armed T-tube because of danger of blocking the orifice of the duct of Wirsung, producing pancreatitis.

Our other serious complication and the only fatality resulted from the technical error of dividing the sphincter too deeply, resulting in a posterior duodenal perforation and leak.

I should like to ask Dr. Walters if he has made studies of the resistance to flow of saline through

the common duct in these postsphincterotomy patients or whether only with the injection of radiopaque material has the spasm, pain, and increased pressure been observed.

DR. WALTMAN WALTERS, Rochester, Minn.: The pressure studies were made with saline and not with the radiopaque thorium dioxide.

This question of whether to use a short tube or a long tube is a very curious one, as is whether to suture the edges of the mucous membrane of the duodenum and the duct. Unfortunately, if a large enough incision is not made through the sphincter of Oddi one cannot see the ampullary opening of the main pancreatic duct in these cases where such an anatomic relationship exists. Also, if one makes too long an incision, there is some separation of the mucous membrane of the wall of the duodenum from the cut edge of the duct and pancreatic fluid digestion of the area may occur.

If the opening into the ampulla is large enough and one looks carefully, one may be able to see the opening of the pancreatic duct if it is present. It often is covered with a little flap of tissue from the ductal wall.

The patient (whose case I reported this morning) who died with acute pancreatitis after sphincterotomy, interestingly enough, was one of the group in whom the main pancreatic duct did not open into the ampulla of Vater but opened about 2 cm. proximal to it, and therefore it could not have been obstructed by a long T-tube.

So, there are some curious things about these cases, and I am sure we have to be cautious about the performance of the procedure except in cases in which there is a definite obstruction, intermittent or continuous, at the sphincter of Oddi.

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Tight Filum Terminale

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and
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Few congenital anomalies of the nervous system are amenable to surgical intervention. In a small number of cases such anatomic malformations are compatible with normal or near normal function until changes in growth produce locomotive or sphincteric disturbances or both. A review of the records of 442 patients with spina bifida occulta seen at the Mayo Clinic in the past decade disclosed six (Cases 1 to 6) with tight filum terminale.

Historical Aspects

Tulpuis in 1641 was the first to use the term "spina bifida." Mention of such anomalies is found, however, as early as the writings of Hippocrates.* Since then the ebb and flow of thought on this most perplexing of biologic phenomena is wondrous, but very little concerns the anchoring filum terminale.

Fuchs † coined the word "myelodysplasia" to explain the relationship of spina bifida, enuresis, and deformities of the feet. De Vries [3] suggested the use of the same term for cases in which symptoms were progressive and were largely of a trophic nature and do not include the typical progressive atrophy and the sensory disturbances of syringomyelia.

Lichtenstein [4] employed the term "spinal dysraphism" for a group of pleomorphic disorders that might be cutaneous, mesodermal, or neural in origin. He noted that neural forms of dysplasia might be present without cutaneous or mesodermal defects. Woltman [5] also observed myelodysplasia without cutaneous or bony anomalies. Lichtenstein [6] again wrote of distant neuroanatomic defects in cases of spina bifida. He believed that alterations that might occur were manifold but dependent on fixation of the spinal cord at an abnormally low level that precluded adequate rostral migration. Resultant deformities observed were in the hindbrain, ventricular system, and blood vessels about the foramen magnum. Additionally, the cauda equina was short, with a low-lying conus medullaris and abnormal stretching of the spinal cord at the site of fixation.

Riley,‡ discussing a paper by Parker and McConnell,[7] suggested that a shortened filum terminale might be the basic cause.

Garceau [8] described three patients in whom progressive paresthesias and difficulties of gait and micturition associated with kyphoscoliosis led to lumbar laminectomy and severance of a thick, tight filum terminale with dramatic abatement of symptoms and signs.

Many others § have reported cases in which the caudal end of the spinal cord was tethered by bands, adhesions, and knots of fibrous tissue; in some, function was improved when tension was relieved.

Embryology

The development of the filum terminale is

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* Cited by Fisher, R. G.[1]

† Fuchs,[2] and Fuchs and Mattauschek, cited by de Vries.[3]

‡ Riley, H. A., in discussion on Parker and McConnell,[7] p. 16.

§ References 9 through 15.

closely bound up with that of the spinal cord and associated structures. Detailed studies have been made by Streeter,[16] Kunitomo,[17] and Kernohan.[18] Beyond the 32nd somite, the neural tube becomes atrophic and a bundle of nerve fibers on its ventral aspect eventually forms the filum terminale. Lengthening of the filum terminale, with subsequent growth of the organism, is the result of degeneration of the primitive conus medullaris and intrinsic increase in length of its nerve fibers.

infants and children seen from 1924 through 1943 at the Children's Hospital, Boston, 205 had the deformity in the lumbar region and 87 in the sacral.

Four of our six patients (Table) were female; two were male. The youngest female was 7 years old; the oldest, 35 years at time of operation. The two males were aged 3 and 12 years, respectively.

As mentioned earlier, a large variety of clinical conditions have been related to spina bifida occulta; these include peripheral and

Vertebral and Other Deformities in Six Patients with Tight Filum Terminale

Case	Sex	Age, Yr.*	Duration of Symptoms, Yr.	Location of Vertebral Defects	Other Deformities
1	M	12	Since childhood	1 and 2 sacral	13 pairs of ribs; fovea sacralis
2	F	12	10 3/4	4 and 5 lumbar, 1 sacral	Sacral fat pad; widened lumbar canal
3	F	35	1½	5 lumbar, 1 to 4 sacral	Hypertrichosis cyst of conus and filum
4	F	7	3	2 and 3 cervical, 4 lumbar, 1 sacral	Fused-thoracic gibbus; rib anomalies
5	F	34	30	3, 4, and 5 lumbar, 1 sacral	Lumbosacral fat pad
6	M	3	Since birth	Lumbosacral	Meningocele

* At time of operation.

Anatomy

The filum terminale, like the lumbar and sacral nerve roots, is not under tension and floats free in the cerebrospinal fluid. It is 24 cm. long. The conus medullaris merges imperceptibly into the filum terminale. The distal extremity of the filum terminale ends in the coccygeal ligament. Harmeier [19] stated that the filum terminale contained all the elements of the spinal cord.

Clinical Features

Little clinical acumen is needed to recognize spina bifida except the occult variety, especially when symptoms occur late in life. Authors seem to agree that 1 infant per 1000 delivered, either living or dead, will be afflicted with spina bifida. Ingraham and Lowry [20] found the incidence of spina bifida occulta to be as high as 25%, and of 546

visceral disturbances. Five authors have written of progression in severity of these disturbances. In most of our cases sphincteric and locomotive difficulties were progressive, with onset in early childhood and accentuation at puberty.

Difficulty with micturition was common. Three of the four children and one of the adults had enuresis or urgency of micturition, or both. The urinary difficulties of one patient were worse in the morning. Another child had retention with overflow; improvement occurred after severance of a taut filum terminale.

Sphincteric disturbances are common in spina bifida occulta and have been noted by many observers. Peritz [21] found that 68% of 22 adults and 35% of 22 children with spina bifida occulta had enuresis. Spiller [22] thought that the development of enuresis after exercise was secondary to stretching

of the cauda equina. Motor and sensory disturbances ensued also.

Meredith [23] presented the case of a 6-year-old girl with bladder difficulty as her chief complaint, the result of spina bifida occulta. A number of strands of the cauda equina were adherent to the dura at the second sacral level. The freeing of these gave much clinical improvement.

All of our patients had locomotive difficulties which ranged from a sensation of stiffness to actual weakness. One girl (Case 2, Table), when aged 11 years, had to stop attendance at ballet classes because of increasing inability to perform fine movements. One woman (Case 3) walked with a limp of the right leg. Another (Case 5) had noted weakness and atrophy of the left leg since the age of 4 years. When she reached high-school age, the weakness had increased and pain in the same leg commenced. In the ensuing years, weakness progressed and numbness commenced. The pain was aggravated by coughing and sneezing. The symptoms were accompanied by limping and stumbling when walking. One girl (Case 4) complained of difficulty in using the left leg and stiffness of the knees for one month. A boy (Case 1) had clawing of the toes of the right foot and stiffness of the knees during the two years before admission. Both symptoms were progressive.

Locomotive difficulties seemingly are twofold, namely, lessened muscular power and stiffness of the legs. Pain in the lower extremities was an additional symptom in four patients.

Deformities were not marked in our cases. Apart from weakness and atrophy of the muscles in the legs, only one patient had deformity of the feet, the clawing of the toes previously mentioned. This is in contradistinction to cases reported by Fuchs,[2] de Vries,[3] and others who listed deformities of the feet as part of the symptom complex. It is possible, however, that if our patients had been left alone, malformations of the feet would have appeared in due course. One patient had kyphoscoliosis, and another had meningocele.

Incoordination was difficult for the patients to describe. They complained of stumbling and falling easily, and one (Case 2) initially had difficulty with fine movements.

Sensory deficits were seen in the two women and the child with meningocele. One woman (Case 3) had additional loss of sensation in the right upper extremity and chest wall. This was probably the result of a syrinx in the cervical region of the cord. In the child, the deficit was in the saddle area, common in meningoceles. The children, although they had no detectable sensory loss there, complained of numbness in the legs. One girl (Case 2) stated that she felt as if she "had no legs at all at times."

A few symptoms were worse in the morning on arising. One patient stated that flexing the head produced a pain in the back and legs.

Clinical Examinations

Clinical examinations elicited signs below the waist, except in the two women. Stigmata of underlying spina bifida were present in five patients. Increased quantities of hair were noted in three, a fat pad in two, and a fovea sacralis in another. A meningocele was present in one child. Spina bifida was seen in all roentgenograms of the lumbar vertebrae (Fig. 1). One patient (Case 1) had 13 pairs of ribs (Fig. 2).

Watching these patients walk revealed a broadening of the base and a lack of ease as they progressed. Those with weakness in one or both legs limped. Occasionally unsteadiness would appear momentarily. More difficult tests such as hopping were poorly done.

The distal muscles of the lower extremities were weak, but not markedly so. On one patient (Case 1) an electromyogram was made, which showed evidence of denervation in the right abductor hallucis brevis muscle. The unopposed action of the short flexors of the toes may well account for the clawing of the toes of the right foot.

Fig. 1 (Case 1).—Lumbar and sacral vertebrae with spina bifida of first and second sacral segments.

Reflexes of the knee were often normal or increased, whereas those of the ankle oftener were reduced. Babinski's signs were equivocal in one and present in another.

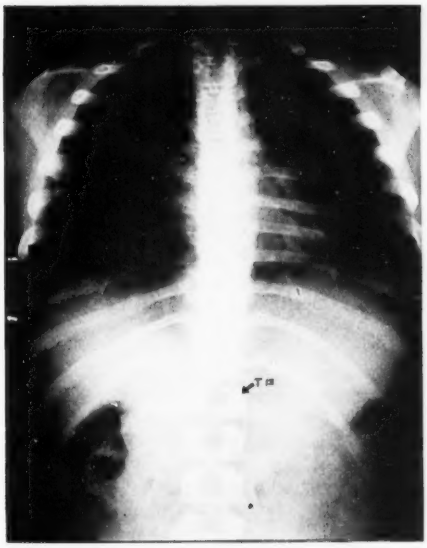

Fig. 2 (Case 1).—Thirteen pairs of ribs.

Anal reflexes were reduced in three. Anal tone was also diminished.

Roentgenograms of the lumbar spine revealed spina bifida in each case. In two the spinal canal was widened. Hintze [24] warned against interpreting x-ray findings in young children as spina bifida, since the laminae may not have fused at an early age.

Air myelography was carried out on two patients; the others had undergone this examination elsewhere. The dural sac in all our cases was displaced backward, and the anterior margin was not deformed by tumors lying in this situation (Fig. 3).

Fig. 3 (Case 1).—Air myelogram; lateral view showing dural sac pulled posteriorly and the anterior margin smooth and continuous.

Differential Diagnosis

A tight filum terminale must be differentiated from other congenital anomalies and tumors and degenerative and inflammatory diseases. The severity of the neurologic deficit in cases of congenital anomalies at an early age should forewarn the clinician. Nevertheless, even when a meningocele is present, exploration should be advocated if progression of symptoms is noted. Boettcher [25] believed that exploration should be performed to avoid the possibility of

later trouble. This is an extreme view and is not held today. Katzenstein [26] advocated awaiting the onset of secondary changes.

Degenerative diseases, such as Friedreich's ataxia, have defects in other systems and familial histories.

Inflammatory lesions may well produce bizarre neurologic deficits, but examinations of spinal fluid, in addition to normal myelographic findings, would rule out a tight filum. Congenital syphilis, apart from positive serologic tests, will present other stigmata of this now uncommon disease.

Tumors, whether intradural or extradural in the region of the conus, may be difficult to evaluate, but rarely does the history extend from babyhood. Extradural cysts and fibrolipomatous tumors produce pain many months before sensory or locomotive disturbances occur. Intensification of sensory deficits and muscle weakness within a short period may well give a clue to the true picture.

When progression of symptoms is seemingly from childhood and is accentuated at puberty, an anchored spinal cord by a tight filum terminale is a strong possibility, and any patient with symptoms and signs of a progressive lesion should be given the benefit of surgical exploration.

Report of Cases

Case 1.—A 12-year-old white schoolboy was first seen at the clinic on Dec. 5, 1955, because of clawing of the toes of the right foot. The family and previous history were not relevant. Clawing of the fourth and fifth toes was first observed two years before and had progressed to the extent that walking with shoes on was painful. Further questioning elicited that in recent months both lower extremities had been stiff at times. Unsteadiness was denied. Very recently, clawing of the fifth toe on the left foot was observed. The boy had been enuretic until 8 years of age, and since then he would occasionally wet his trousers. Bowel difficulties were denied.

General examination was not remarkable and revealed a well-developed adolescent boy. Neurologic examinations showed mildly increased deep tendon reflexes in the legs, a little more so on the left. Babinski's sign was equivocal on the left. Anal reflexes were reduced, and the tone of the rectal sphincter was about 50% of normal. The right calf was thinner than the left by 2 cm. in circumference. There was early pes cavus on the right with clawing of the fourth and fifth toes. Stance, gait, and locomotion were normal except for occasional unsteadiness. A fovea sacralis was present. An electromyogram showed fibrillation potentials and denervation in the right abductor hallucis brevis muscle. Roentgenograms of the lumbar and sacral vertebrae revealed spina bifida of the first and second sacral segments (Fig. 1), and roentgenograms of the chest showed 13 pairs of ribs (Fig. 2). Air myelography outlined the dural sac; its anterior and posterior edges were smooth, and the whole sac was pulled backward in the spinal canal (Fig. 3). No block was found by the Queckenstedt test, and the cerebrospinal fluid was clear, colorless, and watery. The total protein was 40 mg. per 100 ml., and 1 lymphocyte was found per cubic millimeter.

A diagnosis of tight filum terminale was made, and lumbosacral intradural exploration was done. The lower lumbar and upper sacral spines were uncovered, baring a large spina bifida of the upper two sacral segments. No extradural mass was seen. The dural sac was tented over a taut band stretched longitudinally on its inner aspect. When the dura was opened, this proved to be a tight filum terminale. It was severed between clips.

The postoperative course was uneventful, and no urinary difficulties developed. No sensory defects were found. Little change occurred in the deep tendon reflexes or the Babinski response. A few days later corrective operation was done on the right fifth toe. Following an uneventful convalescence, the boy returned home.

Case 2.—A 12-year-old white schoolgirl was seen at the clinic for the first time in October of 1951; her complaint was of difficulty in walking and numbness in the lower extremities. No significant history was obtained relating to pregnancy, birth, or postnatal life. One brother had congenital absence of one kidney and other anomalies.

In the first 11 years of life the child had had attacks of weakness of the legs accompanied by some unsteadiness and vague low back pain. At 11 years she gave up ballet classes because of difficulty in performing fine movements of the feet and legs. Subsequent to a fall on ice when aged 12 years, she had attacks of loss of balance and sensations that "she had no legs." The latter was described as numbness with pins and needles first in the feet and gradually involving legs and thighs. The attacks lasted 5 to 60 minutes and occurred after strenuous activities. She had no particular weakness but felt unable to walk. No bowel difficulty was noted. Frequency of micturition was present.

A dull frontal headache occurred during these

attacks and was made worse by bending forward. Myelography with iophendylate (Pantopaque) done elsewhere was reported as negative.

General examination was not remarkable. Neurologic examination showed diminished abdominal and deep tendon reflexes in each lower extremity. Anal reflexes were also reduced. Babinski's responses were obtained bilaterally and were greater on the right. She had a moderate degree of ataxia when walking. In the sensory examination vibratory and position perception were diminished. Minimal weakness was found in anterior and posterior tibiales and gastrocnemial and gluteal muscles of both sides, but more so on the left. Similar weakness of plantar and dorsiflexor muscles of the toes was present. Romberg's test was positive, and the girl had difficulty hopping on either foot. Fine movements of toes and feet were markedly impaired.

Roentgenograms of the lumbar vertebrae showed spina bifida of the fourth and fifth lumbar and first sacral vertebrae with widening of the spinal canal at the level of the fifth lumbar vertebra (Fig. 4). Routine laboratory studies were negative.

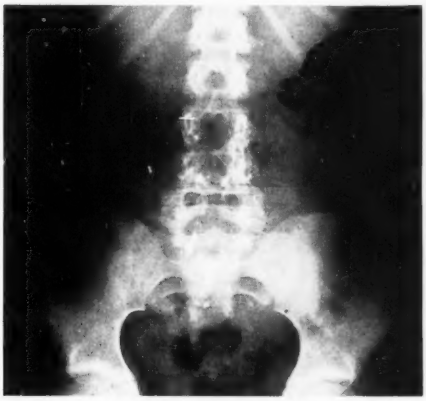

Fig. 4 (Case 2).—Lumbar spine with spina bifida occulta of fourth and fifth lumbar and first sacral vertebrae with widening of the spinal canal.

Lumbar laminectomy was advised because of progression of symptoms. Consequently, on Oct. 12, 1951, under intratracheal anesthesia laminectomy was done. There was maldevelopment of the spinous process of the fourth lumbar vertebra with a large pad of fat overlying this region and compressing the dural sac. Its removal did not seem to explain all the patient's difficulties, and intradural exploration revealed a tight filum terminale with the distal end attached to the dura opposite the fourth lumbar vertebra. A portion was resected, and this allowed the cauda equina to fall back into place. Immediately after operation the patient volunteered the information that she felt much improved. Eight days after operation neurologic examination showed hyperactive deep tendon reflexes, bilateral Babinski responses, and no sensory impairment in the lower extremities. Ataxia was considerably less. Muscle weakness was unchanged, but there was less urinary urgency.

Three months later the patient wrote that she was able to ride her bicycle, walk several miles to school, and partake in the physical-education program.

CASE 3.—The patient, a 35-year-old white housewife, was first seen at the clinic on March 22, 1954. At that time she gave a history of having had pain in the right hip and leg and numbness of the right arm and chest for the past one and one-half years. In 1949, a thyroidectomy had been done elsewhere. Nineteen months before admission she had slipped on ice and fallen on the right hip. A half hour later there was pain. In a week curling of the fourth and fifth toes of the right foot and pain low in the back appeared. She limped on the right leg; the right arm and thorax were numb.

Nine months later (ten months before her visit to the clinic), she fell again; this time she hit the tail bone. Aching pain developed and extended along the posterior aspect of the right thigh to the toes. The pain was not aggravated by coughing or sneezing, and in the ensuing six months certain maneuvers of the right hip would relieve the pain. The numbness of the right arm and thorax did not progress. She had no bowel difficulties but since the first fall had had urgency of micturition.

Results of the general examination, routine laboratory studies, and urinalysis were within normal range.

Neurologic examination showed bilaterally equal but diminished deep tendon reflexes, except that the right triceps brachii reflex was weaker than the left. The right gastrocnemius and dorsiflexor muscles were weak. Sensation was impaired in the right arm and chest wall. There were no signs referable to intracranial structures. The patient walked with a limp, and the right foot had a high arch and hammer toes. Hypertrichosis was evident in the lumbosacral area.

Roentgenographic studies showed spina bifida occulta of the fifth lumbar and first to fourth sacral vertebrae. There was dysplasia of the centrum of the fifth lumbar and spondylolisthesis, Grade 1, of the fifth lumbar on first sacral vertebra with separation of the neural arch. Myelography after injection of iophendylate showed distortion of the oil column opposite the third lumbar vertebra, and the oil would not pass this point. The cerebrospinal fluid was clear, colorless,

and watery and contained 30 mg. of protein per 100 ml. and 1 lymphocyte per cubic millimeter. Manometric studies were within normal limits.

Lumbar laminectomy exposed the loose neural arch of the fifth lumbar vertebra. This was removed, and a large extradural cyst containing clear fluid was found on the right side. After the dural sac was opened, no obstruction was encountered when a rubber catheter (No. 8) was passed rostrally a distance of 16½ in. At the lower end of the conus medullaris and upper part of the filum terminale was a cyst containing opalescent fluid, some of which was the contrast dye. This was opened and a tantalum seton inserted.

The filum terminale was taut, and 0.5 cm. was removed between clips. The ends separated 1.75 cm., and so 1.25 cm. represented tension. Closure was done in anatomic layers.

After operation the patient's legs ached some, but she had no urinary difficulties. Changes had occurred in the deep tendon reflexes and in sensation. The right triceps brachii reflex was absent, and the right knee jerk increased. Ankle jerks were unobtainable on the right and reduced on the left. Plantar responses were normal. No muscle weakness was found in the lower extremities, and only minimal, in the right upper extremity. Superficial sensation of light touch, pain, and temperature was reduced minimally in the anterior aspect of the right thigh and hip, but impairment was greater than before operation in the right arm and chest wall. There was mild pain in the right arm and both legs.

Three months later all pain in the limbs had gone. The sensory deficit was the same, but no bowel or bladder difficulties were noted. A year after operation, the patient was much happier, and neurologic examination done elsewhere showed a considerable reduction in the intensity of the sensory deficit, although reflexes were still reduced on the right side. Gait and locomotion were normal, and the toes were straightening out.

Comment.—This case was complicated by a cervical cord lesion, probably a syrinx. How much the extradural cyst and cyst in the conus medullaris contributed to the clinical status is unknown, but severance of the taut filum terminale and subsequent improvement would impress one that this procedure played the largest part in the recovery.

Case 4.—When first seen at the clinic on Sept. 24, 1948, the patient was 3 months old. Pregnancy, birth, and postnatal course were uneventful apart from feeding difficulties, which were the reason for the first visit. General examination was negative. Roentgenograms showed a gibbus of the upper thoracic region with wedging of the third thoracic vertebral body, no abnormality of the skull, and some anomalies of the ribs.

When the patient was seen again on Aug. 19, 1949, feeding difficulties were not entirely overcome, but roentgenograms of the spinal column did not show progression.

At the next visit in June, 1952, the child was 4 years old. She could sit up when 10 months old, walk at 1½ years, and talk. Apart from increase in the deformity of the chest, fusion of the second and third cervical vertebrae and spina bifida of the first sacral arch with widened interpedicular measurements, the child was normal.

The parents returned with the child in June, 1955, when aged 7 years. In the interim she had been falling down easily, had complained of stiffness of the legs, and had suffered from occipital headaches that forced her to lie down for relief.

General examination was not unusual except for slight increase of hair. The neurologic examination revealed unsteady locomotion with spastic gait. Deep tendon reflexes were hyperactive in both legs, but more so on the left. Babinski's responses were elicited on both sides but were greater on the left. The left anterior tibialis muscle was weak, ocular fundi were normal, and there was no sensory impairment. Roentgenographic examination of the vertebrae revealed only spondylolisthesis of the fifth lumbar on the first sacral vertebra.

At lumbar laminectomy on July 8, 1955, a large dural sac was found lying in a widened spinal canal. Incision into the sac showed a tight filum terminale with attenuated conus medullaris lying opposite the lumbosacral interspace. Additionally, there was a tight coccygeal fiber. Both the latter and the tight filum terminale were severed.

After operation the muscle power of the lower extremities was impaired, especially that of the flexor muscles. Reflexes were hyperactive bilaterally and Babinski's responses were obtained in the left side. Urinary difficulties slowly disappeared, and on dismissal on the 10th postoperative day the patient was able to walk with the aid of crutches.

Five months later crutches had been discarded. Apart from difficulty in controlling the left leg and a feeling of stiffness in the left foot, she was able to walk and ride a bicycle. No sensory deficit was found by the home physician.

Comment.—This case is similar to those described by Garceau,[8] though release of the anchored conus medullaris was the only procedure.

Case 5.—This patient, a 34-year-old white married woman who worked as a secretary, was first

seen at the clinic on July 27, 1953. Her father probably had died of Addison's disease and her mother of liver disease. Two brothers and three sisters were alive and well. She was the mother of two children, both girls, aged 13 and 10 years. Both were living and well. At the age of 8 years the patient had undulant fever, and in the past six years she had had episodes of melena and abdominal pain on the right side. General physical examination disclosed normal conditions except that the possibility of Meckel's diverticulum had been raised.

Neurologic symptoms had commenced at the age of 4 years with weakness and atrophy of the left leg. At adolescence, aching pain appeared low in the back and in the left leg, and weakness and limp became marked. In the interval from then until she was 32 years old, numbness of both lower extremities had appeared and increased, and she had had episodes of low back pain and weakness of the legs. The pain was aggravated by coughing and sneezing. On several occasions she had had urinary frequency, especially in the morning on awakening, and she often had dizzy spells that were alleviated by getting up and walking about. The low back pain was worse after the birth of the first child.

The patient was hospitalized elsewhere in 1951, when she was 32 years old, because of difficulty in emptying the bladder and urgency of micturition. They were noticeably worse in the morning shortly after getting up and would improve somewhat as the day wore on. An iophendylate myelogram was reported as showing normal conditions.

In May, 1952, the woman began to have left hemicrania with scotomata in the left field of vision. These continued until admission. A week after the pain in the head commenced, a burning sensation developed in the region of the right biceps with tingling in the fingers of the right hand. From this time onward she stumbled when walking and had cramps in the left calf with numbness in the right toes. Three months before her visit at the clinic, there was some dysphagia. The sensory symptoms of the feet progressed to the extent that she was unable to determine the difference between hot and cold. The pain in the back had spread so that now it extended over the sacrum and was present when sitting.

Results of the general examination were not unusual except for slight increase of hair. On neurologic examination reflexes were increased a little in both arms. The right quadriceps reflex was markedly increased while the Achilles tendon reflex of the left side was completely absent, and she had difficulty in performing fine movements with the fingers and toes. In both lower extremities and the right upper limb, touch, position, and vibration sensations were normal, while superficial appreciation of pain and temperature was diminished; this was much greater in the distal part of the legs. An unusual amount of hair and a fat pad in the lumbosacral region were observed.

Roentgenograms of the skull and entire spinal column were negative except for spina bifida occulta of the third, fourth, and fifth lumbar and the first sacral vertebrae. The third lumbar interspace was narrowed, and the bodies of the third and fourth lumbar vertebrae were smaller than the others. Ocular fundi and ears, nose, and throat were normal.

On Sept. 3, 1953, the region of the spina bifida was exposed. Yellow ligamentous tissue covered the bony defect; its removal revealed a large dural sac. Inside was a tight filum terminale with some adhesions between the nerve roots on the left side. The motor and sensory components of the fourth lumbar nerve remained separated for a distance of 1 cm. before forming the root. Two centimeters of the filum terminale were resected.

After operation the patient had difficulty in swallowing and pain in the left leg; both symptoms decreased within a few days. Sensation in the legs and urinary function improved. Reflexes were increased in the right arm and in the right leg but were less brisk than before operation: The left ankle jerk was now recorded as —2 on a range of +4 to —4. In sensation, appreciation of superficial pain was still reduced a little in the arms and to a greater extent in the hands and thighs and feet, but was equal bilaterally. Joint and vibratory sense were now diminished about 25% in the feet. The patient returned home after 10 days of hospitalization and in January, 1954, sustained a whiplash injury of the neck in a car accident. There was some pain in the neck but otherwise no change in her symptoms. She wrote in March, 1954, that she was not falling or stumbling, the urinary urgency had decreased, and her legs felt much stronger.

CASE 6.—Patient, a 3-year-old white boy, was first seen at the clinic on Sept. 30, 1955. The main complaint was continuous dribbling of urine since birth. Pregnancy and delivery had been normal; the child could sit up at 6 months, walk at 12 months, and was able to climb at 18 months. Family and previous history were not relevant.

The child had grown and developed normally, but from birth had had a soft fluctuant tumor over the lumbosacral area, which had increased in size concomitantly with the child's growth. The head had not become unduly enlarged, and the child was able to run and walk normally. There was no evidence of mental retardation. The child since birth had continuously wet his clothes but had never stained his trousers with bowel contents. The mother reported that he tended to walk on a wide base.

Apart from the meningocele, no abnormality was found on general examination. Routine studies of blood and urine were within the normal range. Reflexes in the upper extremities and abdomen were within normal range. The cremasteric reflexes were increased, but both ankle jerks were absent. Anal reflexes were absent and plantar responses were down. In the saddle area in the region of the fourth and fifth sacral dermatomes there was no apparent response to pinprick. The child continuously dribbled small amounts of urine, and 170 cc. of residual urine was found on catheterization. There was no abnormality of the upper urinary tract. Roentgenograms of the lumbar vertebrae revealed a spina bifida occulta of the lower lumbar and upper sacral region.

On Sept. 16, 1955, the meningocele was excised. When the sac was opened, the filum terminale, which was tight, was adherent to the lower end of the meningocele opening. This was severed. The defect was closed in layers.

Postoperatively, pain sensation (pinprick) in the saddle area seemed to be returning, as the child objected to the pin. One month after surgery the residual urine was less than 55 cc., and after dismissal incontinence was much less.

Comment.—Although this child had a meningocele and micturition difficulties, locomotion was normal for his age. The only clinical evidence of spinal cord involvement was difficulty with micturition. With severance of the tight filum terminale the residual urine became considerably less. It was felt that in due time micturition would become normal.

Treatment and Results

In each case an intradural lumbosacral exploration was made, and the tight filum terminale was resected. The cut ends separated 1.25 cm. in one patient. No obstruction was found. In one patient the conus medullaris was at an abnormally low level, being at the lumbosacral interspace. The upper lumbar level was not exposed.

Results of operations were gratifying. Recovery seemed commensurate with severity of preoperative symptoms and signs. The young ballet dancer was now able to return to her dancing. The two most noticeable improvements both objectively and subjectively were loss of urinary urgency and unsteadiness of gait. Additionally, the low back pain was relieved.

Comment

It is difficult to correlate symptoms and signs with possible pathologic changes. A diligent search of the literature has failed to uncover descriptions of the spinal cord in cases of tight filum terminale. None of the patients described by Garceau [8] or in our series has died.

However, pulling on the filum terminale with the proximal end of the spinal cord fixed produces an elongation and narrowing in all transverse directions of the conus medullaris and, to a less extent, the lumbar enlargement. This was done with spinal cords removed at necropsy. Additionally, many of the smaller surface vessels become narrowed. It is conceivable that in a taut filum terminale similar changes are produced and accentuated by changes in the relationship of spinal cord to vertebral column during phases of growth and during movement and sleep.[27]

The spinal cord is relatively mobile within the spinal canal. The latter lengthens, not only during growth but also from day to night, and with varied positions of head, neck, and trunk.

Curvatures of the vertebral column undergo major changes.[28] In the fetus and newborn there is one curve concave ventrally with the axis of vision angulated downward. The cervical curve appears when the visual axis becomes horizontal and the head can be held up. The lumbar curve develops as the child assumes the upright position and walks. This has the effect of lengthening the canal. At puberty growth of the vertebral column speeds up. The spinal cord continues its growth in length but at a much slower pace. Thus any fixation of the lower end of the cord will produce disturbances of function by increasing tension on the cord.

Symptoms were severer in the morning in some of our cases. Eaton [27] showed that during sleep the vertebral column length-

ened. This was explained partly by flattening out of the curves and partly by increased depth of the intervertebral disks. The latter was thought to result from increased water content. After the upright position was maintained for a few hours, the curvatures become more pronounced, the intervertebral disks thinner, and the vertebral column shorter. In flexion the vertebral canal lengthens 7 cm., and the dural sac becomes stretched.

Three patients also noted pain in the legs when the head and neck were flexed. This is known to produce traction on the lower end of the spinal cord and nerve roots.

It is postulated that in cases in which the filum terminale is tight, continued traction will produce degenerative changes in the cells and fibers in the lower part of the spinal cord. These are probably permanent if maintained for a sufficient time. The children in this series improved markedly. The two adults improved too but not as much as the children.

Failure of the filum terminale to lengthen is probably of intrinsic origin and is probably one of the many possible defects that can occur during maturation.

Summary

A few patients with congenital anomalies have urinary dysfunction and locomotive and gait difficulties during early childhood. These are accentuated at puberty and should undergo intradural lumbosacral exploration in search of a tight filum terminale. Severance of this structure corrects what seems to be a hopeless neurologic deficit.

DISCUSSION

DR. E. S. GURDJIAN, Detroit: This very excellent paper by Dr. Love and Dr. Jones has introduced a timely subject. The study of involvement of the spinal cord and the spinal nerves by abnormalities of the suspensory ligament of the spinal cord, that is, the filum terminale, and the dentate ligaments, is receiving more and more attention in recent neurosurgical studies.

However, the frequent way of diagnosing this condition is by elimination and exploration rather than a positive diagnostic method of evaluation before operation.

We find that myelography is of great value in determining the exact etiological factors of disability. The five Slides will show some of the aspects of these problems.

[Slide] The first two Slides are an example of an intrasacral meningocele with a traction of the dural sac in a 2-year-old child with a weakness of one lower limb. This Slide shows that there is a huge meningocele in the sacral portion of the spinal canal.

[Slide] In the lateral view you notice the backward displacement of the column of iophendylate (Pantopaque) in the lower end into the sac area. In this particular instance the traction on the dural sac and the filum terminale is unquestioned.

[Slide] Here is another example of an extensive abnormality of the lower end of the spine by the presence of a spina bifida occulta, with some hair growing over this area. This patient, 36 years of age, had complaints comparable to those Dr. Jones enumerated in one of his cases, namely, weakness in the lower extremities and sphincter disturbances.

[Slide] The myelogram shows a serious defect in the lower end of the spine, but above the spina bifida.

[Slide] This lesion at operation was found to be a rather large dermoid cyst along one side of the spinal cord, which appeared to be covered with fatty material; the dermoid is shown in the Slide in relation to a 25-cent piece.

I should like to ask Dr. Love and Dr. Jones if they like myelography in these cases and to what extent has myelography helped them to diagnose the disease prior to operation. Also, do they ever diagnose this particular condition prior to operation and find the traction syndrome proved by operation?

DR. PETER HYWELRIS JONES, Rochester, Minn.: In answer to Dr. Gurdjian's two questions, we have found myelography to be of great value. The cases that we have performed myelography on have been three in number. The other patients had myelography performed elsewhere. Findings were reported as being normal.

One of the classic cases was one of the last we saw, a young boy of 14, in whom the diagnosis was made on clinical grounds alone and was confirmed at surgery. His story was one of enuresis from childhood, urinary urgency, and clawing of the toes. In his case an air myelogram showed the dural sac to be pulled backward and there was no deformity along the ventral aspect, which might suggest a tumor or protruded intervertebral disk.

I think the diagnosis can be made clinically if one takes into consideration the symptoms of enuresis, urgency of micturition, and difficulties of locomotion that have progressed. These symptoms

usually are accentuated at the age of puberty, when the vertebral column grows much faster than the spinal cord.

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Arteriovenous Fistulae and Arterial Aneurysms of the Pulmonary Arterial Tree

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and
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This short presentation deals with two patients with pulmonary arteriovenous fistulae and one patient with bilateral pulmonary arterial aneurysms. Extensive clinical investigations have been carried out on two of these patients before they were subjected to resection therapy. Plastic bronchovascular cast injection studies were made of the specimen from one patient with pulmonary arteriovenous fistulae. A lung from the third patient who was not operated upon but who died owing to a brain abscess complicating multiple pulmonary arteriovenous fistulae supplied the specimen for another vinyl plastic cast injection.

Pulmonary Arteriovenous Fistulae

Many years elapsed between the original pathologic description of pulmonary arteriovenous fistulae by Wilkens in 1917 [36] and the first clinical diagnosis of this disease entity by Reading in 1932 [26] and by Smith and Horton in 1939.[31] Several years later the first resection of this anomaly was reported by Shenstone.[29] Recently a review by Sloan and Cooley [30] summarized 85 case reports which had appeared in the literature prior to 1953.

Clinical Findings.—Our two patients presented most of the usual clinical findings associated with pulmonary arteriovenous fistulae. These are well documented in the literature and include cyanosis, clubbing of the fingers and toes, polycythemia, and occasionally a continuous bruit audible over the chest wall in the region of the lesion. These patients usually do not show cardiac enlargement. In the review of Sloan and Cooley,[30] 38 of 50 reported patients exhibited hemangiomata of the skin and mucous membranes. The latter clinical findings which are usually associated with the Osler-Weber-Rendu syndrome * were found in one of the patients we are reporting. A familial history of cutaneous telangiectatic lesions is frequently obtained in these patients, and these may not become apparent until after puberty.

Etiology.—It has been stated by previous investigators that clinically significant spontaneous arteriovenous fistulae result from the persistence of developmental arteriovenous communications.† Support for this hypothesis is presented by the findings in one of our plastic bronchovascular cast injections (Fig. 1). In the area surrounding the obvious arteriovenous fistulae there were visible communications between small, normal-sized terminal arteries and veins. This finding was not noted in remote areas in the same specimen or in other injected specimens made from patients with other disease processes. It is conceivable that the persistent and originally small arteriovenous communications are the basis for the development of clinically significant lesions in later life. Increased blood flow through areas of decreased resistance resulting in progressive enlargement of the afferent

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* References 25, 28, and 35.
† References 9 and 27.

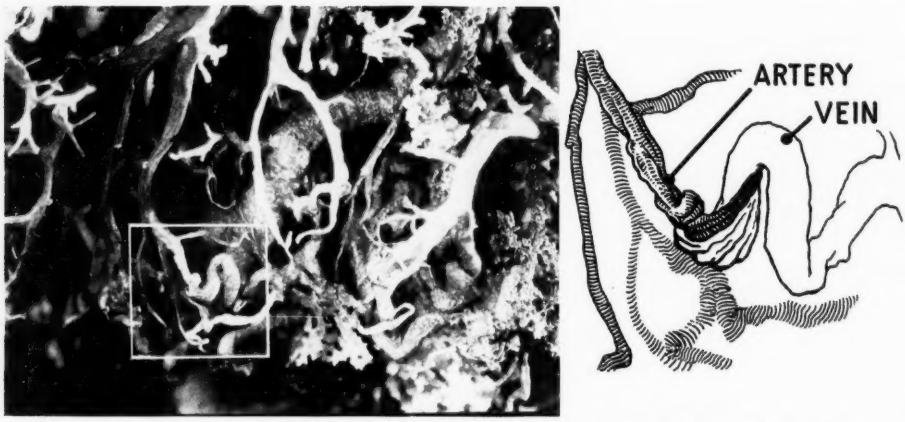

Fig. 1 (Case 1).—Plastic bronchovascular cast showing small, nondilated, terminal arteriovenous communication. (See text.)

arterial vessels is a well-recognized pathologic process.

Diagnostic Studies.—Lesions of this type should be readily diagnosed by the employment of chest roentgenograms, fluoroscopy, laminography, angiocardiography, pulmonary function studies, and cardiac catheterization. The Valsalva and Müller maneuvers during cardiac fluoroscopy should demonstrate a change in the size of the radiologic density with changing intrathoracic pressures. Angiocardiography is the most valuable single procedure which may be employed. The size, configuration, and multiplicity of the lesions can be accurately demonstrated. A high incidence of bilateral involvement will be encountered. We employed pulmonary arteriography during operation in one instance to localize a previously ill-defined peripheral fistula. Pulmonary function studies and cardiac catheterization will demonstrate the presence of a right-to-left pulmonary vascular shunt. Systemic arterial blood will show persistent oxygen desaturation in spite of breathing 100% oxygen. The oxygen saturation of pulmonary capillary blood in uninvolved areas of the lung is normal. The cardiac catheterization findings in our patient resembled those described by Friedlich, Bing, and Blount.[12] Right ventricular and systolic pulmonary artery pressures were normal. The pulmonary artery pulse pressure was increased owing to a lowered diastolic pressure.

Treatment.—Inasmuch as all of these patients are or will become symptomatic, it is necessary to evaluate each one as a candidate for surgical therapy. Brain abscesses, septicemia, and massive hemoptysis are frequently encountered causes of death.‡ In order to select patients for resection therapy, it is necessary to carry out the aforementioned diagnostic procedures. These should determine the location and multiplicity of the lesions and thereby assist in the selection of candidates for extirpative surgery. A few patients may be encountered in whom the arteriovenous fistulae are so numerous that surgical therapy would be of no benefit to the patient.[8]

Complete eradication of the fistulae may require multiple segmental and at times bilateral resections. Excellent results can be expected if all the shunts are excised and a maximal amount of normal pulmonary parenchyma preserved.§

Case Reports

Case 1.—A 55-year-old white housewife was first admitted to University of Iowa Hospitals on March 18, 1953. Admission was prompted by the

‡ References 6, 17, 32, and 33.

§ References 1, 2, 13-15, 18, 19, 22, 24, 34, 37.

discovery of a "coin lesion" in the right lung on a routine chest roentgenogram. Her only complaint was exertional dyspnea. There was no family history of pulmonary or cutaneous vascular abnormalities. The positive findings on physical examination were mild cyanosis of the lips and nail beds and clubbing of the fingers and toes. The hemoglobin was 15 gm. per 100 cc. and the red blood cell count 5,000,000 per cubic millimeter. A chest roentgenogram revealed bilateral multiple densities in the lower lobe areas. Angiocardiography demonstrated these to be arteriovenous communications (Fig. 2). The electrocardiogram was within normal limits. The patient was discharged and readmitted on Sept. 9. Cardiac catheterization was performed on Sept. 11. The peripheral arterial saturation was 16.7 vol. % (82% saturated). A low diastolic pressure was noted in the pulmonary artery. The remainder of the findings were within normal limits (Table 1).

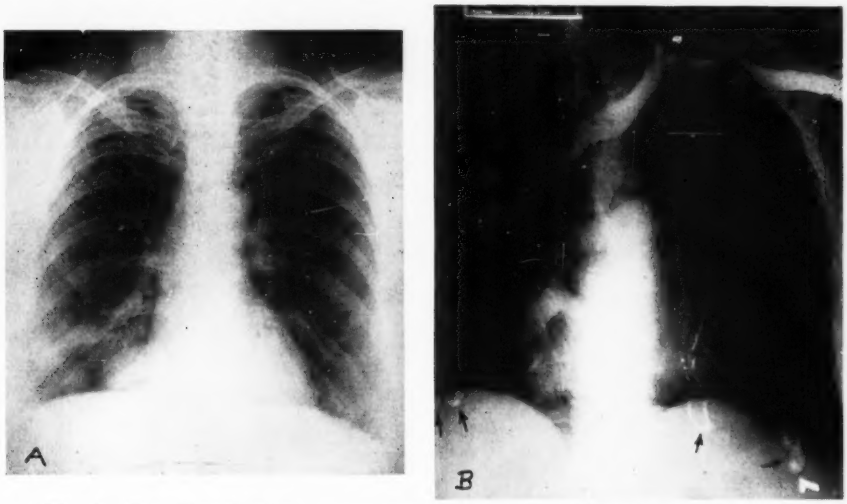

Fig. 2 (Case 1).—*A*, chest roentgenogram demonstrating bilateral lower lobe arteriovenous fistulae; *B*, angiocardiogram showing opacification of the arteriovenous fistulae.

Operative Findings (Right Side).—The basilar segments of the right lower lobe and a pericardial cyst which was found incidentally were resected on Sept. 24. Multiple subpleural fistulae measuring 0.5 to 1 cm. in size were visible in the lower lobe at operation. The pulmonary arterial branches to the basilar segments were enlarged. Blood aspirated from the superior pulmonary vein had an oxygen content of 20 vol.%, while that drawn from the inferior pulmonary vein draining the right lower lobe containing the fistulae exhibited an oxygen content of 18.6 vol.%.

The patient was discharged on the seventh postoperative day following an uneventful convalescence and was readmitted for further surgical treatment on Nov. 23. There had been no change in the patient's symptoms.

Operative Findings (Left Side).—On Dec. 2 segmental resections of the lingula, superior segment of the left lower lobe, and anterior segment of the left upper lobe were carried out for multiple arteriovenous fistulae. Pulmonary arteriography was employed at operation using a portable x-ray machine and a 5×7 in. cassette which was wrapped in a sterile rubber sheet. The cassette was placed inside the thoracic cavity and posterior to the lower lobe. Pulmonary arteriography was carried out by injecting 10 cc. of 70% sodium acetrizoate (Urokon) into the pulmonary artery proximal to the lower lobe. This procedure was used to assist in localizing a small fistula within the basilar segment of the lower lobe. The fistula had been visible on the preoperative roentgenograms obtained by intravenous angiocardiography but was not demonstrable at operation. This small fistula could not be accurately localized, although demonstrated by arteriography, and was not removed. The patient was discharged on the eighth postoperative day in good condition.

Cardiac catheterization was again carried out on Aug. 5, 1954. The only abnormality found was a slight elevation of the proximal pulmonary artery pressure. The peripheral arterial oxygen saturation was 95%, and this rose to 100% while the patient was breathing 100% oxygen. The patient was relieved of her mild cyanosis. These findings were interpreted as demonstrating that no dynamically significant shunts remained (Table 1).

TABLE 1.—*Preoperative and Postoperative Catheterization Studies, Case 1*

Location	Blood Pressure, Mm. Hg		Oxygen Content, Vol.%	
	Preoperative	After Bilateral Resections	Preoperative	After Bilateral Resections
Right atrium	6/0	13/8	13.0	
Right ventricle	18/0-11/0	32/11	12.9	
Proximal right pulmonary artery	14/2	26/12	11.8	
Distal right pulmonary artery	6-(-1)	11/11	19.9	
Proximal left pulmonary artery	12/2-9/0	33/14	12.4	11.97
Pulmonary artery after exercise 1 min. 3 min. 5 min.	 17/4-15/2 13/2-15/5 11/2-16/5	 46/18 38/15 31/15		
Femoral artery At rest During exercise	125/65		16.7 (82% saturated) 16.0 (78% saturated)	
Brachial artery at rest		140/75		16.46 (95% saturated)

Preoperative	
Cardiac output (resting)	4.1 liters/min.
Cardiac output (during exercise)	5.4 liters/min.
Cardiac index (resting)	2.1 liters/M ^{2}/min.
Cardiac index (during exercise)	2.7 liters/M ^{2}/min.
Stroke volume (resting)	59.0 cc.
Stroke volume (during exercise)	62.0 cc.
Postoperative	
Cardiac output (resting)	4.04 liters/min.
Cardiac output (during exercise)	7.65 liters/min.
Cardiac index (resting)	1.98 liters/M ^{2}/min.
Cardiac index (during exercise)	3.75 liters/M ^{2}/min.
Stroke volume (resting)	68.0 cc.
Stroke volume (during exercise)	68.0 cc.

Surgical Pathology.—The resected pulmonary tissue from both lungs showed similar findings. There was a twofold increase in size of the pulmonary arteries and veins supplying the involved segments. The subpleural bleb-like fistulae were thin-walled and easily compressed (Figs. 3 and 4). A vinylite plastic bronchovascular cast of the basilar segments of the left lower lobe was made after the technique described by Liebow and coworkers[21] (Fig. 5). The tortuous and dilated fistulous areas were beautifully demonstrated. Mixing of the differently colored plastic which was injected separately into the pulmonary artery and vein could be demonstrated. This occurred in the region of the fistulae. One large basilar segmental artery supplied the pulmonary segment containing the fistulae while three venous branches drained this area. An interesting finding was the demonstration of very small communications between terminal pulmonary arteries and veins in the proximity of the main fistulae (Fig. 1). These communications were not visible elsewhere in the same specimen, nor have they been noted by us in injected specimens made from pulmonary tissue obtained from patients with other disease processes.

CASE 2.—This 27-year-old white man was admitted to the State University of Iowa Hospitals on Dec. 29, 1951. His mother stated that the patient had had convulsive seizures involving the left side of the body for 14 hours preceding admission. The patient had experienced frequent epistaxis all his life. The patient's mother, maternal aunt, and sister gave the history of frequent episodes of epistaxis. A sister had died following a brief episode described as a "head injury." His maternal aunt subsequently underwent exploratory laparotomy at the University of Iowa Hospitals for an intra-abdominal arteriovenous fistula which was localized at the time of operation to the hepatic artery region but was not removed. Further history revealed that approximately four to eight members, principally male, of each of the preceding five generations of this family had been known to exhibit mucocutaneous telangiectatic lesions. Two of the patient's children were subsequently examined, and neither one of these showed cutaneous manifestations similar to those observed in the other members of the family.

Physical examination revealed that the patient was cyanotic, but alert and cooperative. There were multiple small telangiectatic areas involving the face, hands, trunk, and oral mucous membranes. Clubbing of the fingers and toes was noted, which had been observed since infancy by the patient's parents. There was an apical systolic murmur.

Fig. 3 (Case 1).—Operative photograph showing the multiple subpleural arteriovenous fistulae in the left lower lobe and lingular segment of the left upper lobe.

underwent tracheotomy on the eighth postoperative day. Cardiac arrest occurred and resuscitative measures were unsuccessful. Postmortem examination revealed multiple bilateral pulmonary arteriovenous fistulae, mucocutaneous telangiectasias, and the aforementioned brain abscess.

Surgical Pathology.—The left lung weighed 250 gm. There were two large arteriovenous fistulae located in the left lower lobe. Plastic injection studies of this lung were attempted but were unsuccessful, owing to the large size of the fistulae, which prevented filling of the remainder of the pulmonary vascular tree. Microscopic examination of the areas containing the vascular anomalies revealed numerous dilated, thin-walled vascular channels. The pathologic diagnosis was hereditary hemorrhagic telangiectasia with pulmonary arteriovenous fistulae. The right lung weighed 350 gm. Two fistulae measuring 1 cm. in diameter each were found subpleurally in the middle lobe. The largest fistulae was located in the anterior segment of the right upper lobe. Other fistulae were identified in the superior segment and in the posterior basilar segment of the lower lobe. A vinylite plastic bronchovascular cast was made of this

Fig. 4 (Case 1).—Low-power photomicrograph demonstrating the dilated subpleural vessels; left lower lobe.

The blood pressure was 120/80 mm. Hg. No bruit was audible over the chest or abdomen. Laboratory studies revealed a hemoglobin of 17 gm. per 100 cc. and red blood cell count of 6,230,000 per cubic millimeter. A chest roentgenogram revealed bilateral discrete densities which did not show pulsations during chest fluoroscopy (Fig. 6). The patient experienced several grand mal seizures during the next few days. A left facial paralysis developed. On his fifth hospital day, a brain abscess was excised from the right frontal lobe. Actinomyces and Gram-positive cocci were cultured from the exudate. The patient

lung (Figs. 7 and 8). The pulmonary arterial radicals entering the fistulae were found to be enlarged two to three times their normal size, while the veins were of nearly normal caliber. The small terminal arteriovenous communications which were noted in Case 1 were not found in this specimen. The bronchial arterial tree was not injected with plastic material and was not examined.

Pulmonary Arterial Aneurysms

Pulmonary arterial aneurysms are very rare lesions and have most frequently been

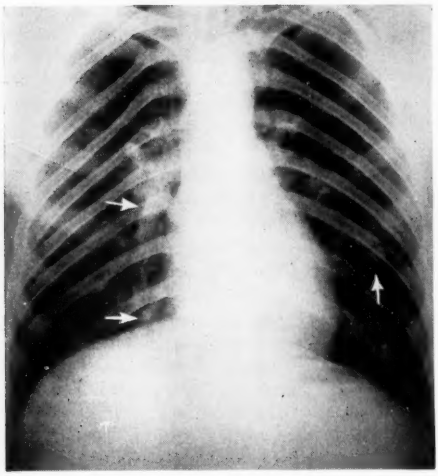

Fig. 6 (Case 2).—Chest roentgenogram showing multiple arteriovenous fistulae.

encountered as postmortem findings.[7] In two extensive reviews of the literature by Boyd and McGavack in 1939[4] and by Deterling and Clagett in 1947,[10] a total of 147 reported cases were summarized. Since that time, only a few sporadic reports have appeared in the literature.‖ We found data of preoperative angiocardiography in three of these patients and cardiac catheterization results in only one instance.[23]

A certain amount of confusion appears to exist in the literature regarding the classification of these lesions. A distinction must be made between aneurysmal dilatations of the pulmonary artery and true pulmonary artery aneurysms. True aneurysms exhibit pathologic changes consisting of degeneration of the vessel wall, as has been stated by Deterling and Clagett.[10] Aneurysmal dilatations of the pulmonary artery without degenerative changes in the vessel wall are frequent findings in patients with increased pulmonary blood flow or pulmonary hypertension. Thus, these vascular abnormalities when noted to accompany intracardiac and great vessel lesions such as patent ductus arteriosus, septal defects, mitral stenosis, etc., should not be classified as true pulmonary artery aneurysms. One is then left with a relatively small group of lesions which probably occur either on a developmental, infectious, or arteriosclerotic basis. The bilateral arterial aneurysms in the patient which we are presenting were probably caused by primary pulmonary hypertension associated with a bacterial endarteritis.

Diagnostic Studies.—Patients with true pulmonary artery aneurysms do not exhibit signs of peripheral arterial desaturation, clubbing of fingers and toes, or polycythemia. These patients do show signs of right-sided hypertrophy such as precordial prominence of the chest wall, overactive right ventricle, and electrocardiographic signs of right heart strain. Harsh systolic murmurs may be audible overlying the aneurysms. Cardiopulmonary fluoroscopy will reveal expansile pulsations of the lesions. Intravenous angiocardiography will demonstrate opacification of the aneurysm. Cardiac catheterization in our patient demonstrated elevated right ventricular and pulmonary artery pressures (Table 2). These findings were also noted in the patients reported by MacKenzie and Clagett.[23]

Treatment.—It is difficult to define indications for surgical intervention in a disease entity which is so rarely encountered. Massive hemoptysis and bacterial endarteritis, both of which occurred in our patient, probably represent the main indications for surgical therapy. Reports of two successful excisions of true pulmonary artery aneurysms have been found in the literature.¶ To the best of our knowledge our patient represents the sole instance in which bilateral pulmonary arterial aneurysms were diagnosed preoperatively and in which bilateral surgical resections were attempted.

Case Reports

Case 3.—This 5-year-old white boy was first admitted to the State University of Iowa Hospitals on June 25, 1952. A cardiac murmur and low exercise tolerance had been noted since the age of one year. Physical examination revealed no evidence of cyanosis. There was a Grade 1, coarse,

‖ References 3, 5, 11, 16, 20, and 23.

¶ References 20 and 23.

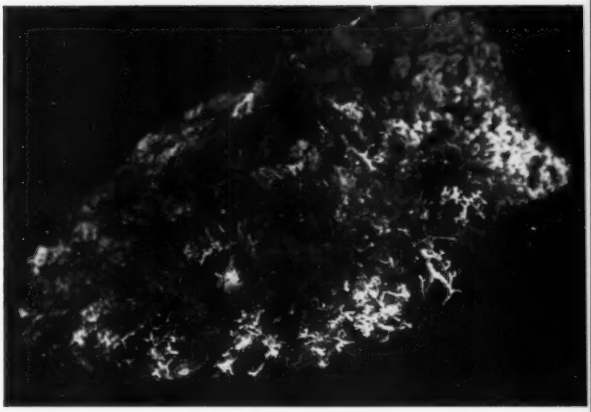

Fig. 5 (Case 1).—Plastic bronchovascular cast. Basilar segments of the left lower lobe, showing the mixture of pulmonary artery and vein plastic in the fistulae.

Fig. 7 (Case 1).—Plastic bronchovascular cast. Left lung, showing multiple arteriovenous fistulae. Bronchial tree, white; pulmonary artery, red; pulmonary vein, green.

Fig. 8 (Case 2).—Plastic bronchovascular cast, showing two of the arteriovenous fistulae.

TABLE 2.—*Preoperative Catheterization Studies, Case 3*

Location	Blood Pressure, Mm. Hg	Blood Oxygen Content, Vol. %
Superior vena cava		9.2
Right atrium	3-5/0	9.6
Right ventricle	95-110/0-2	9.5
Proximal pulmonary artery	88-108/7-14	10.4
Distal pulmonary artery	8-12/2-4	9.3
Femoral artery	150-160/60-70	14.4 (84% saturated)
Cardiac output	3.3 liters/min.	
Cardiac index	4.1 liters/M^2/min.	
Stroke volume	30 cc.	

systolic murmur present in the left third intercostal space. Chest roentgenogram and cardiac fluoroscopy revealed evidence of right ventricular hypertrophy and a prominent pulmonary artery conus. The patient was discharged and given an appointment for cardiac catheterization at a later date.

The patient's second hospital admission was on April 1, 1953. During the preceding three months the patient experienced intermittent fever and hemoptysis. A three-day episode of painful swollen joints of the upper extremities was noted. Six weeks prior to this admission the patient was hospitalized in his home city with a temperature elevation of 104 F, dyspnea, and hemoptysis. A chest roentgenogram revealed a right upper lobe pneumonia. A blood culture was positive for hemolytic Staphylococcus aureus. The white blood cell count was 23,000 and the hematocrit value 35%. The patient slowly improved under digitalis, oxygen, and antibiotic therapy. At the time of transfer to University of Iowa Hospitals the right upper lobe pneumonitis had largely resolved. There was an aneurysmal-like opacity in the left hilus which had not been present in his chest roentgenogram taken one year previously. Two blood transfusions were given during the first two weeks of hospitalization to replace blood loss resulting from massive hemoptysis. Intravenous angiocardiography revealed opacification of round densities located in the right upper and left lower lobes. (Fig. 9). Cardiac catheterization was car-

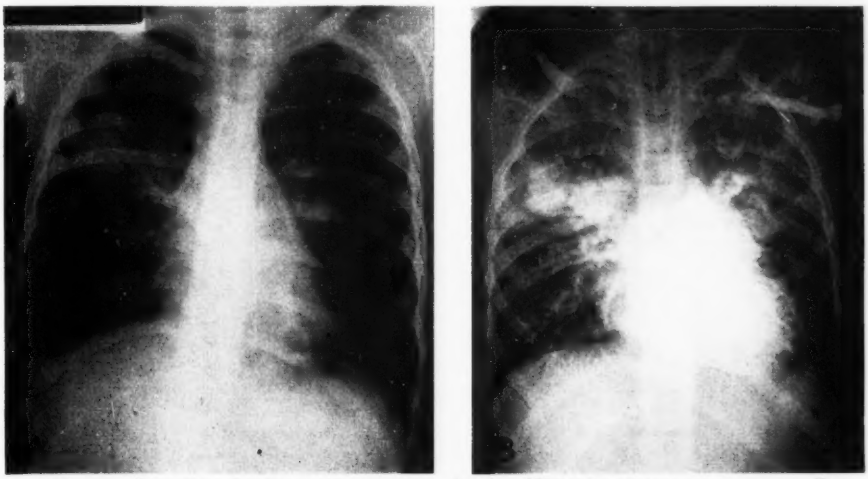

Fig. 9 (Case 3).—*A*, chest roentgenogram showing bilateral pulmonary aneurysms. *B*, angiocardiogram demonstrating opacification of the aneurysms.

ried out on June 5, at which time the right ventricular and pulmonary arterial pressures were found to be significantly elevated, with a range of 90-110 mm. Hg systolic pressure (Table 2). The pulmonary artery pulse pressure was increased with an average pressure of 95/10 mm. Hg. The femoral arterial oxygen saturation was 14.4 vol.% (84% saturated). These findings were interpreted as showing questionable evidence of a right-to-left intrapulmonic shunt and the presence of pulmonary hypertension.

Operative Findings (Right Side).—On June 16, a right upper lobectomy was carried out. Inflammatory reaction about the upper lobe hilus was encountered. A pulsating mass measuring approximately 3 cm. in diameter was palpable within the upper lobe near its hilus. The heart was normal to inspection and palpation. Postoperative convalescence was uneventful, and the patient was discharged on June 23. The patient's final admission occurred on July 8. He had remained, in the meantime, essentially asymptomatic on restricted activity. The patient was prepared for left thoracotomy and excision of the pulsatile mass in the left lung hilus.

Operative Findings (Left Side).—At the time of left thoracotomy, on July 9, a pulsating aneurysm of the pulmonary arterial branch supplying the basilar segments of the left lower lobe was dissected free and excised with the left lower lobe. Extreme tachycardia accompanied by a rectal temperature of 104 F was noted at this time. Ventricular fibrillation appeared followed by irreversible cardiac standstill. At the time of necropsy, no further abnormalities were found in the heart. Death was attributed to ventricular fibrillation occurring during pulmonary resection in a patient with severe pulmonary hypertension and multiple pulmonary artery aneurysms.

Surgical Pathology.—The right upper lobe was the site of a pulmonary artery aneurysm which measured 5 cm. in diameter. The wall of the aneurysm was densely fibrotic and contained only scanty amounts of elastic tissue (Fig. 10). There was evidence of a local endarteritis. Arteriovenous communications were not demonstrable. The aneurysm of the left lower lobe pulmonary artery measured 3 cm. in diameter and arose opposite the artery leading to the superior segment of the lower lobe. Histologic examination of the wall of the aneurysm revealed findings similar to those observed in the aneurysm removed with the right upper lobe. Arteriovenous communications were clearly not demonstrable in this aneurysm. Microscopic examination of the lung revealed marked medial hypertrophy of the pulmonary artery branches (Fig. 11).

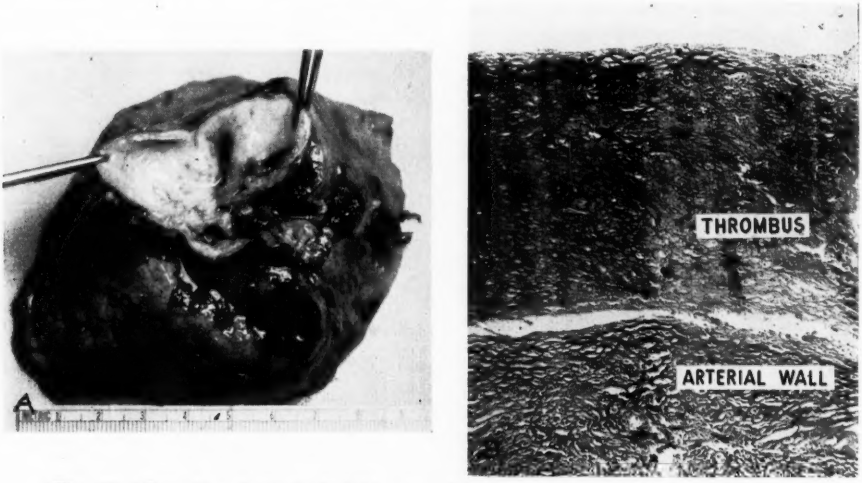

Fig. 10 (Case 3).—*A,* excised right upper lobe showing the thickened aneurysm wall. *B,* photomicrograph of the aneurysm wall. Degenerative changes are present in the arterial wall. An organizing thrombus is attached to the intimal surface.

A 4-year-old brother of the patient was known to have a cardiac murmur for one year. Cardiac fluoroscopy established the probable diagnosis of pulmonary hypertension. Cardiac catheterization was carried out on July 29, 1954. With the exception of a moderate elevation of the right ventricular pressure, (58/7 mm. Hg) and pulmonary arterial pressures (55/17 mm. Hg), no abnormalies were detected. Peripheral arterial oxygen saturation was normal. These findings were interpreted as indicating the presence of pri-

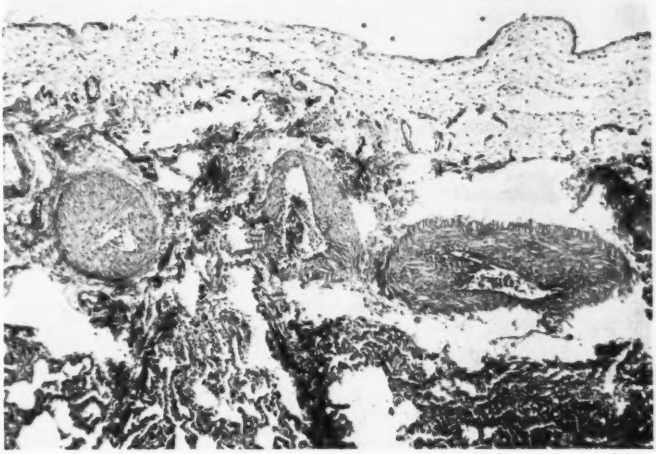

Fig. 11 (Case 3).—Photomicrograph of lung showing marked medial hypertrophy in the peripheral pulmonary arterial branches.

mary pulmonary hypertension. This child is under periodic observation at this hospital, and to date no evidence of aneurysmal dilatation of the pulmonary arteries has been found.

Summary

The literature pertaining to pulmonary arteriovenous fistulae and pulmonary artery aneurysms has been reviewed. Two patients with pulmonary arteriovenous fistulae are reported. One of these patients had been subjected to angiocardiography and catheterization before and after bilateral resections of the vascular anomalies. The surgical specimens obtained from this patient and a lung obtained after death from another patient were studied by means of plastic bronchovascular cast injections. Those studies support the hypothesis that the pulmonary arteriovenous fistulae are the result of persistence of developmental arteriovenous communications.

In addition, a patient is reported with bilateral pulmonary artery aneurysms. We believe that the pathogenesis in this patient was based on primary pulmonary hypertension complicated by bacterial endarteritis. Criteria for establishing the diagnosis of true pulmonary artery aneurysms are discussed. This patient was studied preoperatively by angiocardiography and cardiac catheterization.

DISCUSSION

DR. JOHN L. KEELEY, Chicago: I hesitate to present this case because it certainly does not compare with the very beautifully documented cases we have just seen demonstrated by Dr. Taber.

Very recently we encountered a case of pulmonary arteriovenous fistula in a 30-year-old lawyer, whose chief complaint was that of fatigue. He had been considered to have tuberculosis for six or seven years because of a shadow in the chest x-ray, and because he had hemoptysis. In addition, he had a gastrointestinal hemorrhage and telangiectatic lesions in the mucous membrane in his mouth. The diagnosis of Rendu-Osler-Weber's syndrome had not been made until a recent reevaluation of his symptoms and findings.

[Slide] The only shadow that we could see on the x-ray studies seemed to be in continuity with the branch of the pulmonary artery to the right lower lobe. Other x-ray studies failed to show any evidence of another lesion, although we understood thoroughly that a second one had not been completely ruled out.

I have a short movie strip that I think will tell a little more of the story.

This patient had polycythemia, clubbing of his fingers, and cyanosis of his lips. He had moderate arterial oxygen unsaturation. Because of the possibility of brain abscess, fatal hemoptysis and hemothorax, we suggested that he submit to operation.

[movie strip] This short movie strip shows the lesion in the lung. It proved to be in the right lower lobe, in an area where the superior, lateral, and posterior basal segments came together. After the hilar dissection was completed, it was found impossible to obliterate this pulsation by

occluding any three of the four branches of the pulmonary artery to the lower lobe and, therefore, a lobectomy was done.

This little blue spot on the lung is the only evidence on the surface of the lung. You can see that the pulsation involves a fair area. This section of the movie strip, made when all of the vessels were occluded, shows no pulsation just before the lobectomy was completed.

The patient has made an uneventful recovery. Immediately after operation it was evident that the cyanosis had disappeared. The red blood cell count, which had been over 6,000,000 originally, is now in the range of 4,000,000 to 4,500,000, and the hematocrit value, which was 51%, has remained stable at 45%.

DR. WILLIAM E. ADAMS, Chicago: We have seen a very beautiful demonstration of the features presented by this problem. My interest in it began in 1942, since which time we have had three additional cases.

I look upon this as a malformation of the lung, of the vascular type, rather than especially separate from any congenital malformation. In other words, this vascular type of malformation may be present in some cases of the so-called pulmonary type or cystic disease. It was present in about 10% of some 56 cases that we have studied.

My remarks will be confined to the first case that we operated on in 1942 (it was reported shortly thereafter), since I think some of you will be interested in the follow-up course.

The patient had two fistulae in the left lung which required a left pneumonectomy. His blood desaturation and other changes reverted to normal shortly thereafter, and he remained well for about six years. At the end of that time x-rays showed several shadows in the right lung, caused by three separate arteriovenous fistulae. He had again a return of the blood changes that were present when he was originally seen, desaturation and other features.

It was thought that the lesions on the right side might be treated surgically, in spite of his having no left lung, if they were sufficiently isolated and could be obstructed. For this purpose and study at operation, an oximeter of the recording type, developed by Dr. John F. Perkins Sr. and our Physiology Department, was used and was very helpful.

At operation, the lesions were found in a favorable location for excision, and the three were excised—or, in one case, obliterated—by multiple sutures. The patient got along after that without too much difficulty and returned to normal activity. His blood picture again reverted to normal status.

The second operation was in 1949, and for several years thereafter he was called in for follow-up study. About a year and a half ago I heard that he had died, the cause of death being unknown. He was engaged in unskilled labor, but there was no report of a hemorrhage.

In view of the fact that this man had had the development of these three fistulae on the opposite side six years after the first operation, it makes me think that these lesions arise from a vascular malformation which may be insignificant, allowing only a small amount of blood to pass through when they are first developed, but that as time goes on, they enlarge and permit a greater amount of shunt.

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Surgical Management of the Complications of Reflux Esophagitis

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Knowledge regarding the esophagus is probably more deficient than is that of any other organ of the gastrointestinal tract. Attention has been drawn only relatively recently to a condition characterized by inflammation and ulceration of the terminal portion of the esophagus that leads in some instances to fibrosis and stricture. The term "reflux esophagitis" has been given to this condition because of its frequent occurrence under circumstances leading to the reflux of acid or alkaline secretions into the esophagus. Many clinical states may lead to reflux esophagitis, and the forms of treatment are equally diverse. This lack of uniformity in management is particularly apparent when surgical therapy is considered. The purpose of this paper is to discuss the indications for operation, the choice of operative procedure, and the results of treatment. In addition, a new surgical procedure will be discussed briefly.

Review of Literature

Several excellent studies of the problem of reflux esophagitis have been published in recent years.* The esophageal mucosa appears to be inordinately sensitive to the deleterious effects of acid or alkaline secretions. It is rare for a patient who is achlorhydric to have esophagitis. Chief among the causes of reflux esophagitis secondary to the reflux of acid gastric secretions is a sliding esophageal hiatal hernia. Other causes are excessive vomiting and operations that destroy or bypass the gastroesophageal mechanism. Reflux esophagitis caused by regurgitation of alkaline secretions may occur whenever alkaline intestinal contents are brought into contact with the esophageal mucosa, as after total gastrectomy. The medical measures that have been suggested in the management of this disease are not considered in this presentation.

Under certain circumstances, surgical treatment must be instituted. Esophagitis secondary to a sliding esophageal hiatal hernia should be treated by surgical reduction of the hernia if the patient is not obese and if contraindications to operation are absent. However, when the lesion is associated with a short-esophagus type of diaphragmatic hernia or when it is secondary to other predisposing causes, the operative management becomes more complicated.

A number of surgical procedures have been proposed. Wangensteen and Leven [8] postulated that subtotal gastric resection would reduce drastically the acid secretion, with subsequent healing of the esophageal lesion (Fig. 1*a*). Some type of esophagogastrectomy probably is employed oftenest.[9] This procedure may consist of limited resection of the stomach and esophagus (Fig. 1*b1*), or extensive resection of the acid-bearing part of the stomach may be done (Fig. 1*b2*). Experimentally, a procedure

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Section of Surgery (Dr. Ellis and Dr. Clagett) and the Section of Medicine (Dr. Andersen), of the Mayo Clinic and Mayo Foundation. The Mayo Foundation is a part of the Graduate School of the University of Minnesota.

* References 1 through 7.

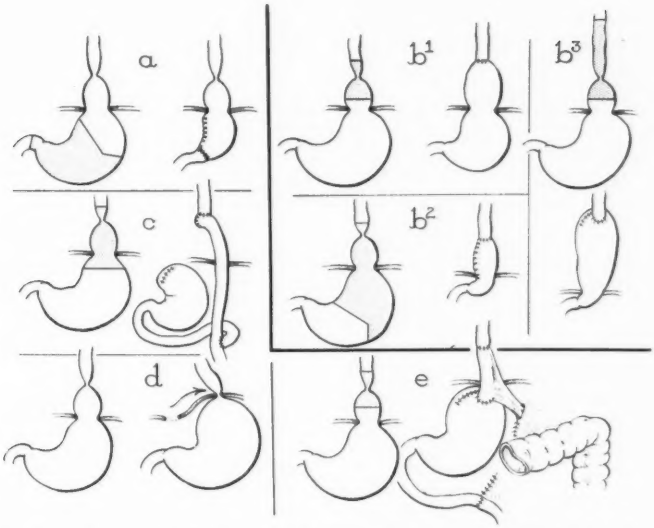

Fig. 1.—Operative procedures for complications of reflux esophagitis: (*a*) subtotal gastric resection; (*b*) esophagogastrectomy: (*1*) limited resection, (*2*) extensive resection of stomach, (*3*) extensive resection of esophagus with high esophagogastrostomy; (*c*) esophagogastrectomy with Roux-Y esophagojejunostomy; (*d*) transplantation of esophagogastric junction to dome of paralyzed diaphragm; (*e*) esophagogastrectomy with interposition of limb of jejunum between esophagus and stomach.

of the latter type has been followed less often by esophagitis than has limited esophagogastrectomy.[10] Valdoni [11] had expressed a preference for extensive resection of the esophagus with esophagogastric anastomosis carried out high in the thorax because, in his experience, esophagitis rarely occurs after a high esophagogastric anastomosis (Fig. 1*b3*). However, Sweet and associates [9] reported follow-up data on 18 patients treated in this fashion and found only 5 to be asymptomatic, whereas 3 of 4 patients undergoing esophagogastrectomy with extensive resection of the stomach were found to have no symptoms after operation.

Allison [12] stated that esophagogastrostomy of any type is to be avoided when the complications of reflux esophagitis are treated. He has preferred to resect the strictured region, close the open end of the stomach, leaving it in situ, and anastomose the esophagus to a Roux loop of jejunum (Fig. 1*c*). He and da Silva [13] reported that 19 of 27 patients who have survived this operation eat slightly small but otherwise normal meals and maintain their weight.

Another proposal is that of Merendino and associates [14] and Effler and Ballinger.[15] Being of the opinion that regurgitation of acid gastric juice will not occur if the esophagogastric junction lies in the abdomen, they have advocated transplanting the esophagogastric junction in cases of short-esophagus diaphragmatic hernia to the dome of the paralyzed diaphragm, thus returning it to an intra-abdominal position (Fig. 1*d*). More recently, a new operation has been reported by Merendino and Dillard.[16] Having demonstrated no unusual susceptibility of the jejunum to acid peptic digestion, they have interposed a limb of jejunum between the stomach and the esophagus in patients undergoing resective procedures on the cardia (Fig. 1*e*). At the time of their report, patients with reflux esophagitis on whom this procedure had been carried out had not experienced recurrence of symptoms.

Miscellaneous procedures that have been proposed include vagotomy, plastic procedures on the esophagus, segmental resection of the esophagus, esophagogastrostomy with formation of a valvular opening,[17] and the use of a gastric tube to replace the esophagus.[18] Vagotomy done alone or combined with other procedures to reduce acidity has been rejected by Allison[1] on the grounds that it is inadequate to prevent recurrence of esophagitis. Sweet and associates[9] found that only one of five patients undergoing esophagoplasty was asymptomatic following the operation. Other methods have been proposed to replace the esophagus, including use of plastic tubes[19] and use of the colon[20] or long segments of jejunum.[21] The replacement of long segments of esophagus is seldom necessary in the surgical management of the complications of reflux esophagitis.

Present Study

Because of complications of reflux esophagitis, 45 patients have been operated on at the Mayo Clinic from 1946 to 1955, inclusive. Patients with esophagitis who underwent surgical reduction of a diaphragmatic hernia are not included. There were 33 male patients and 12 female. Their ages ranged from 17 to 77 years, the average being 43.1 years. Surgical intervention has been carried out with increasing frequency in recent years, 21 of the 45 operations having been done in the last two years covered by the study.

Etiologic Factors.—The causes of reflux esophagitis in this group of 45 patients are listed in Table 1. The condition in 27 patients was initiated by an esophageal hiatal hernia. The disease process had progressed so that at the time of operation a short-esophagus type of diaphragmatic hernia was present. It is our belief that the great majority of such types of hernias follow a sliding esophageal hiatal hernia and are not congenital in origin.[22] Reflux esophagitis developed in 10 patients after excision or destruction of the cardiac "sphincter" carried out as treatment for cardiospasm. In five of these cases, the operation consisted of a cardioplasty, either of the Wendel or Heyerovsky-Grondahl type. The findings in these five cases serve to reemphasize the fact that procedures of this type should be abandoned in the surgical management of cardiospasm. Limited esophagogastrectomy with esophagogastrostomy had been done on two patients, and the disease process in two instances followed a Heller esophagocardiomyotomy. Although this latter procedure is currently favored in the surgical treatment of cardiospasm, occasional cases of postoperative esophagitis are being reported.† Reflux esophagitis in one of our cases followed hydrostatic dilation of the distal portion of the esophagus and the cardia.

TABLE 1.—*Causes of Reflux Esophagitis*

Cause	Cases
Esophageal hiatal hernia	27
Excision or destruction of the cardiac "sphincter"	10
Vomiting, postoperative or secondary to obstructing duodenal ulcers	6
Indeterminate	2
Total	45

The association between duodenal ulcer and esophagitis is well known.‡ Of the 45 patients, 10 had duodenal ulcers. The development of reflux esophagitis in six of these patients appeared to be related directly to the ulcers. One patient's symptoms followed postoperative vomiting after suture of a perforated duodenal ulcer. In five patients, reflux esophagitis was associated with obstructing duodenal ulcers.

Definite abnormalities other than an incompetent cardia could not be detected preoperatively in two patients. Patients unquestionably exist who have incompetent cardias in the absence of diaphragmatic hernias or other demonstrable abnormalities.

Indications for Operation.—The indications for operation in patients suffering

† References 11 and 23.

‡ References 6 and 22.

from reflux esophagitis parallel to a great extent those for duodenal ulcer. As stated previously, esophagitis in the presence of a sliding esophageal hiatal hernia should be treated by surgical reduction of the hernia if the patient is not obese and if contraindicating circumstances are absent. A trial of medical treatment in the form of an ulcer diet, use of antacids, and elevation of the head of the bed is justified in an attempt to control ulcerative esophagitis associated with short-esophagus diaphragmatic hernias or caused by other conditions. When strictures develop, bougienage is of value in maintaining an open gullet. Occasional episodes of mild bleeding likewise may respond to medical efforts, although one would be reluctant to continue such a therapeutic approach in the face of massive hemorrhage.

Because medical management of the complications of esophagitis is often unsatisfactory, early surgical intervention is justified when such complications, namely, formation of strictures, intractable pain, and hemorrhage, have developed. Perforation of an esophageal ulcer also may occur. Although we have encountered patients who have undergone so-called spontaneous rupture of the esophagus, their previous histories did not suggest chronic ulcerative esophagitis; therefore, they are not included in this study.

The principal indications for operation in this group of 45 patients are listed in Table 2. Nearly all patients complained of multiple symptoms; only the chief one that appeared to demand surgical intervention in each case has been listed.

TABLE 2.—*Indications for Operation in Reflux Esophagitis*

Indication	Cases
Esophageal obstruction	20
Intractable pain	17
Hemorrhage	8
Total	45

Operation was undertaken in 20 patients primarily for the relief of esophageal obstruction caused by stricture. Many of these patients had been treated by bougienage for varying periods before surgical intervention. Pain that did not respond to intensive medical efforts required surgical treatment in 17 patients. The pain was either epigastric or substernal and frequently was described as "burning." Although bleeding of some degree occurred in 23 of the 45 patients, it was the major indication for operation in only 8. All but two of these eight patients were anemic at the time they were examined, and all gave histories of repeated episodes of bleeding in the past, necessitating multiple transfusions in most instances. However, emergency operation was required to control massive bleeding in only one instance.

Mention should be made of another reason for operation that was an additional indication in five of our patients; this reason is to exclude the possible presence of carcinoma of the esophagus. Clinical findings, particularly those gained by esophagoscopy, in most instances will permit an accurate diagnosis of the cause of esophageal disease. Occasionally, however, the possibility of a malignant lesion of the distal portion of the esophagus in a patient whose chief complaint is dysphagia cannot be ruled out. Under such circumstances, surgical exploration should be undertaken promptly.

TABLE 3.—*Operations Employed in Treatment of Complications of Reflux Esophagitis*

Operation	Cases	Postoperative Deaths
Esophagogastrectomy	25	
Esophagogastrostomy	11	1
Esophagojejunostomy	5	1
Esophagogastrostomy and antrumectomy	9	
Subtotal gastric resection	16	
Miscellaneous	4	
Total	45	2 (4.4 %)

Operative Procedures.—A number of operative procedures were employed in the

management of these 45 cases (Table 3). Resection of the involved region was usually a tedious and difficult procedure because of the pronounced inflammatory reaction in the tissues surrounding the zone of ulcerative esophagitis. Bleeding was often profuse and difficult to control. Bleeding persisted postoperatively in two patients, and they succumbed to shock secondary to loss of blood.

Esophagogastrectomy was done on 25 patients. This consisted in 11 instances of resection of a portion of the stomach and esophagus, with restoration of the continuity of the alimentary tract by esophagogastrostomy. Limited resection of the stomach and esophagus was done on 4 of these 11 patients. In three patients, two-thirds to three-fourths of the stomach was removed with a small segment of esophagus. Extensive resection of the esophagus was done on the remaining 4 of these 11 patients, followed by esophagogastrostomy high in the thorax. One of these patients died after operation.

Of the 25 patients who underwent esophagogastrectomy, 5 had resection of a portion or all of the stomach and a portion of the esophagus, with restoration of continuity of the alimentary tract by esophagojejunostomy, employing a Roux loop of jejunum as described by Allison and da Silva.[13] One of these patients died in the postoperative period.

A new operative procedure was employed in the nine remaining patients who had esophagogastrectomy. This technique involved bilateral vagotomy, resection of a portion of the stomach and esophagus, and resection of the antrum of the stomach. Continuity of the alimentary tract was reestablished by esophagogastrostomy and gastroduodenostomy in eight patients, and by gastrojejunostomy in one. This procedure will be described briefly in another section.

Sixteen of the forty-five patients, nine of whom also had duodenal ulcers, underwent subtotal gastric resection. The four remaining patients underwent miscellaneous procedures; one had bilateral vagotomy, one had excision of an esophageal ulcer, one had a Heller operation to relieve esophageal obstruction, and the final patient had transplantation of the esophagogastric junction to the dome of the diaphragm, so that the stomach occupied an intra-abdominal position.

Results of Surgical Treatment

The results of operation reported herein must be considered as preliminary, for almost half of the procedures were done during the last two years of the study. Conclusions regarding the new operation to be described must be particularly tentative, since the first operation of this type was performed only a year prior to completion of the study. Nevertheless, review of the results is of some value, since most of the bad results became apparent relatively soon after operation.

TABLE 4.—*Results of Operations for Complications of Reflux Esophagitis*

Operation	Patients Followed	Results		
		Good	Fair	Poor
Esophagogastrectomy				
Esophagogastrostomy	9	3	3	3
Esophagojejunostomy	4	2	2	
Esophagogastrostomy and antrumectomy	9	8	1	
Subtotal gastric resection	15	8	2	5
Miscellaneous	4	1	1	2
Total	41	22 (54%)	9 (22%)	10 (24%)

Results are classified as good, fair, or poor (Table 4). Patients classified as having good results are essentially asymptomatic. Patients with fair results may complain of occasional symptoms but have been able to return to work and in most instances either are maintaining their weight or have gained weight. The group with poor results have had recurrence of pain or dysphagia, or both, necessitating further treatment.

Esophagogastrectomy with Esophagogastrostomy.—Of the nine patients in this group who have been followed, three have

had good results, three have had fair results, and three have noted poor results. Esophagoscopy has not been done postoperatively on the three patients with good results because they have been asymptomatic, but it has been done on all of the remaining six. All six gave evidence of esophagitis that varied from mild superficial inflammation to deep ulceration and stricture. One of the patients was achlorhydric even after stimulation by means of histamine. Sweet's group[9] wisely has warned against the assumption that symptoms following esophagogastrectomy necessarily are caused by esophagitis. They stated that esophagoscopy alone can establish the presence or absence of esophagitis. By this method, recurrent disease was found in six of our group of nine patients undergoing esophagogastrectomy. It was of mild degree in three, being associated with minimal symptoms.

The results in this small group of patients do not indicate that any one type of resection is better than another. Thus, of the patients who had poor results, one had limited resection of the stomach, one had extensive resection of the stomach, and the third had extensive esophageal resection with esophagogastrostomy high in the thorax. Of the three patients who experienced good results, two had limited resection of the stomach and one had extensive esophageal resection with anastomosis high in the thorax.

Esophagogastrectomy with Esophagojejunostomy.—None of the four surviving patients on whom esophagojejunostomy was performed after esophagogastrectomy experienced a return of preoperative symptoms. Two patients are classified as having only fair results, however, because they have trouble eating and maintaining their weight.

Esophagogastrectomy with Esophagogastrostomy and Antrumectomy.—As already noted, nine patients have been operated on during the past year by this new method. Eight of the nine patients have had good results so far. A few of them have had temporary diarrhea during the postoperative period, and some experienced mild symptoms of "dumping" that eventually disappeared. Of the eight patients who experienced good results, none has had recurrence of dysphagia or pain and all are able to eat regular meals without discomfort. Esophagoscopy carried out on two patients seven and four months after operation, respectively, revealed regurgitation of gastric contents into the esophagus but no esophagitis. In one patient, who had scleroderma of the esophagus, one dilation has been necessary since operation, and this patient is, therefore, classified as having only fair results. Esophagitis was absent in this patient at the time of esophagoscopy.

Subtotal Gastric Resection.—Follow-up information is available on 15 of the 16 patients who underwent subtotal gastric resection. Eight of the patients had good results, whereas results in two were only fair and five had poor results.

The preoperative symptoms in the eight patients in whom good results were obtained consisted mainly of epigastric or substernal pain. Dysphagia was absent or mild, and esophageal stricture was not found at esophagoscopy or on roentgenologic examination of the esophagus before operation. One of the two patients who experienced fair results was operated on because of esophageal obstruction. Although esophageal dilation has been required postoperatively, the frequency with which this treatment has been required has decreased. Operation was done on the second patient because of bleeding; periodic episodes of dysphagia have occurred postoperatively, but esophageal dilation has not been required. All five patients who had poor results have needed repeated esophageal dilation after operation, and persistent pain has been a problem in three of them. Although all five of these patients have needed repeated postoperative dilation, the indication for operation in all but one was pain and not esophageal obstruction. Some dysphagia was present in each patient but not enough to necessitate

dilation before operation. One must conclude that healing of the ulcerative esophagitis occurred after gastric resection with subsequent development of an esophageal stricture.

Miscellaneous Procedures.—Only one of the patients undergoing one of the miscellaneous procedures had good results. This patient had minimal dysphagia before operation, the indication for surgical intervention being severe epigastric and substernal pain. Symptoms have been relieved completely after transplantation of the esophagogastric junction to the dome of the paralyzed diaphragm. The patient who had vagotomy and the one who had a Heller procedure not only have had persistent pain and dysphagia but have had secondary operations for their management elsewhere. The patient whose ulcer was excised needed repeated esophageal dilation after operation for several months. For the last year, however, he has had no significant dysphagia.

Comment.—The results of surgical treatment in the management of the complications of reflux esophagitis on the whole have been disappointing. When all operations are considered, only 22 of 41 patients who have been followed have had good results. When patients who have had the new operation are excluded, only 14 of a total of 32 patients 44% had good results.

Our experience with esophagogastrectomy of the conventional type does not parallel that of Sweet and co-workers,[9] who reported that 26 of 28 patients undergoing this operation had good results. Of 23 of these patients who were interviewed directly, however, only 8 were asymptomatic. Because of the small number of cases included in our series, definitive statements cannot be made regarding the relative merits of extensive or limited resection. Even esophagogastrectomy with removal of all of the acid-secreting portion of the stomach and esophagoantral anastomosis was followed by undesirable after-effects that were mild but definite.

Reestablishment of the continuity of the alimentary tract by esophagojejunostomy may be accompanied by severe loss of appetite, difficulty in eating, and failure to gain weight. After subtotal gastric resection, a large percentage of our patients needed continued treatment because of persistence of the preoperative symptoms or because of esophageal obstruction subsequent to healing of the ulcerative esophagitis. The good results were all in patients whose main preoperative symptom was pain, not dysphagia. Esophageal stricture was absent in these patients. When subtotal gastric resection was done on patients whose chief complaint was esophageal obstruction due to stricture, esophageal dilation continued to be required after operation, although the interval between dilations was lengthened. In addition, patients who had severe ulcerative esophagitis but no stricture tended to acquire esophageal strictures as the ulcerative region healed after gastric resection. Subtotal resection conceivably might be carried out with hope of good results in patients who have superficial esophagitis without stricture. Poor results are to be anticipated in patients who have pronounced esophageal strictures or deep ulceration of the esophagus. Stricture of the esophagus is likely to develop after subtotal gastric resection for the latter lesion.

New Operative Procedure

Because of dissatisfaction with the surgical methods currently employed in the treatment of the complications of reflux esophagitis, a new approach to the problem was sought. It was postulated that a satisfactory operation for the condition should (1) remove the obstructed or ulcerated portion, (2) prevent the reflux of acid gastric contents into the esophagus, (3) maintain as closely as possible the normal anatomic pathway for ingested food, and (4) allow the patient a suitable pouch for ingested food.

An operation was designed to fulfill these criteria. The cardia and lower part of the esophagus are excised, bilateral vagotomy is done, and the lower portion of the stomach,

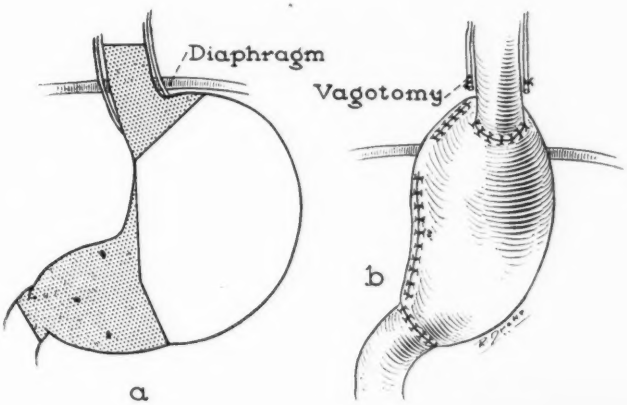

Fig. 2.—New operative procedure: (*a*) Shaded portions indicate extent of resection. (*b*) Continuity of the alimentary tract is reestablished by esophagogastrostomy and gastroduodenostomy; bilateral vagotomy is done.

including the antrum, is excised. The proximal portion of the stomach is anastomosed to the esophagus and the distal end to the duodenum (Fig. 2). The technical details of this procedure are described elsewhere.[24] After this procedure has been done, a satisfactory gastric reservoir remains and physiologically normal continuity of the alimentary tract is maintained. In addition, bilateral vagotomy eliminates the cephalic phase of gastric secretion, and resection of the antrum eliminates the gastric phase of gastric secretion. Thus, gastric acidity is greatly reduced, the intestinal phase only remaining. Experience with this procedure on animals has been reported.[25] A short summary of the clinical record of the first patient on whom this procedure was carried out at the clinic follows.

Report of a Case

A 44-year-old grocery clerk came to the clinic in November, 1951, because of burning substernal pain and blood-streaked vomitus. He had noted a temporary period of dysphagia two years previously. Six months before admission, he experienced the onset of burning substernal pain that was worse at night and when he was recumbent. This was associated with some blood-streaked vomitus.

Roentgenologic examination revealed an esophageal hiatal hernia with 5 cm. of stomach above the diaphragm. Esophagoscopy disclosed severe ulcerative esophagitis in the lower portion of the esophagus. Stricture was absent. The hernia appeared to be of the short-esophagus type.

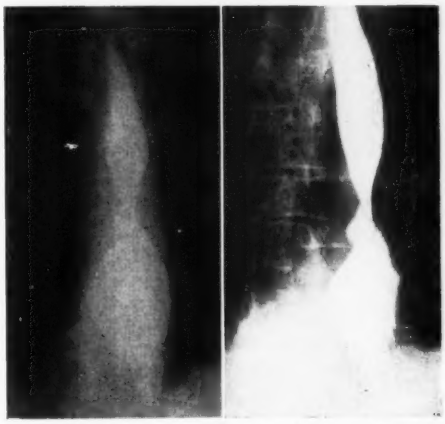

Fig. 3.—Posteroanterior and right anterior oblique esophagograms showing short-esophagus type of diaphragmatic hernia with stricture and ulceration.

The patient was instructed in a medical program and did well for almost three years, until three months prior to his second admission in January, 1955. Complaints at that time were recurrent substernal burning pain and dysphagia.

Roentgenologic studies at that time revealed a short-esophagus type of diaphragmatic hernia with stricture and probable ulceration in the region of the esophagogastric junction (Fig. 3). Esophagoscopy showed pronounced ulcerative esophagitis but little evidence of stricture.

Because of the failure of medical measures to control the disease, operation was advised. Through a thoracoabdominal incision, the distal portion of the esophagus and the cardia were resected, bilateral vagotomy was done, and the distal portion of the stomach, including the antrum, was re-

moved. Continuity of the alimentary tract was reestablished by esophagogastrostomy and a Schoemaker-Billroth I gastroduodenostomy. The surgical specimen showed esophagitis and a chronic ulcer at the esophagogastric junction; a similar specimen removed from another patient is illustrated in Figure 4.

Fig. 4.—Pathologic specimen in another case, demonstrating deep esophageal ulceration and surrounding esophagitis.

Convalescence was uneventful, and the patient was dismissed home 12 days after operation. He returned in six months, having gained 10 lb. (4.5 kg.). He did not have any pain or dysphagia and was able to eat "anything." Gastric analysis disclosed absence of free acid after a test meal. Esophagoscopy did not reveal any esophagitis.

When last heard from, a year after his operation, the patient was asymptomatic.

Summary

Attention has been drawn again to the problem of reflux esophagitis, particularly as it concerns the surgeon. The operative procedures that have been suggested in the management of this disease are briefly discussed.

A total of 45 patients with complications of reflux esophagitis have undergone operation at the Mayo Clinic in the past 10 years. The cause of the esophagitis was esophageal hiatal hernias in 27 patients, excision or destruction of the cardiac sphincter in 10, and vomiting, either postoperative or secondary to obstructing duodenal ulcers, in 6. Two patients had incompetent cardias in the absence of other demonstrable disease. Indications for operation were esophageal obstruction in 20 patients, intractable pain in 17, and hemorrhage in 8.

A number of operative procedures were employed, including esophagogastrectomy of various types and subtotal gastric resection. Of 41 patients who have been followed, 22 54% were considered to have good results.

Dissatisfaction with the results of conventional surgical measures has led to trial of a new operative procedure, which includes excision of the lower part of the esophagus and the cardia, bilateral vagotomy, and excision of the lower part of the stomach, including the antrum. The proximal part of the stomach is anastomosed to the esophagus and the distal end to the duodenum. Short-term results in the nine patients so treated have been encouraging.

DISCUSSION

Dr. William E. Adams, Chicago: Dr. Ellis has presented what seems to be an excellent procedure based on sound physiological principles for the management of what sometimes is a very difficult problem.

The reflux of acid into the lower esophagus may be from one of two sources, namely, neurogenic or hormonal. The various operative procedures which were listed on the slide show how there has been, until recent years, not too good an understanding of the normal physiology of the esophagus as well as its alterations under some of these abnormal conditions. Therefore, the reason for failure of a good percentage of these procedures.

In our thinking on this subject I have always wanted to preserve as much of the stomach as is consistent with the relief of symptoms. I should like to show two or three slides which will indicate better our thinking along these lines and our manner of handling this subject.

[Slide] The first slide shows a diagram of two different procedures. Dr. Sweet has been in favor of the procedure shown on the left, as Dr. Ellis mentioned; but, unfortunately, this does not get rid of the humoral factor in the production of acid and therefore, unless the stomach is drained, there is very apt to be a return of peptic esophagitis in a considerable number of patients.

The drawing on the right illustrates an elevation of the fundus of the stomach, with a lateral

anastomosis, a vagotomy, and a drainage procedure lower down than illustrated here, in the antrum of the stomach. Unless this drainage is low enough to be adequate, there is apt to be puddling with subsequent gastritis and reflux esophagitis.

These cases, of course, differ considerably in the amount of scarring and the amount of ulceration. In some patients I am sure that a resection is advisable; in others, I think that a bypass above the point of obstruction will be adequate.

[Slide] Here is an example, a boy who had had obstruction for about 12 years. He was 17 at this time. The obstruction was complete. The barium was partly swallowed and partly entered through a gastrostomy tube.

[Slide] This shows the results following pulling up of the fundus of the stomach with a lateral anastomosis with the esophagus, a vagotomy, and pyloroplasty for drainage below.

It might very well be that resection of the antrum is a better drainage procedure than a low gastroenterostomy, or a pyloroplasty. The principle underlying the treatment, however, is the same.

[Slide] This brings out an important factor to keep in mind in the treatment of this condition, that is, the frequency with which carcinoma may be found at the esophagogastric junction in these cases. We had 2 carcinomas in a series of 23 cases of short esophagus. In other words, it is a fairly frequent occurrence, much more frequent than in the normal population.

Dr. Richard A. Rasmussen, Grand Rapids, Mich.: This discussion has to do with a serious problem which may be commoner than many realize. It undoubtedly occurs often in association with hiatal hernias. Any study of this stricture problem of the lower esophagus will show that these strictures occur also with various abdominal operations and are frequently associated with the use of a Levin tube.

Conservative therapy is always indicated, of course, and it takes many forms, usually dilatation of various types. Some will be satisfactorily handled in this way. Many will require more radical surgical treatment.

The number of operations which have been described and the information in the literature, it seems to me, are evidence of the unsatisfactory nature of the treatment.

I should like to mention briefly an operation which I did on a man some six months ago, and which has been perfectly satisfactory to date. This 50-year-old man was operated upon in June, 1953, to correct an esophageal hiatal hernia. There was a 6 cm. sac containing stomach and some omentum herniated through an enlarged hiatus. The lower esophagus was moderately dilated and the wall thickened, this consistent with the preoperative endoscopic findings of esophagitis and redundancy. The diaphragm was opened, and the stomach was drawn down and sutured to its inferior surface. The hiatus was narrowed appropriately and the diaphragm was closed. The immediate course was uneventful, but within three months it was apparent that distress was still present. Some 15 months after operation esophagoscopy was again done, at another city, and a stricture was found to be present just above the hiatus area. There was difficulty in passing a size 31 F. dilator. Dilations were continued and the size was increased to 45 F. by using a string, but they were most difficult. The stricture was at a 38 cm. level. Reoperation was decided upon.

A simple wedge or segmental type of excision of the stricture of the lower esophagus was done. A direct end-to-end anastomosis was made. A careful vagotomy was done above the site of anastomosis, and then a posterior gastroenterostomy.

The excised stricture segment was 4 cm. in length and showed an ulcerated esophageal mucosa at one end and gastric mucosa at the other. There was evidence of inflammation and fibrosis.

This man has a good result to date. Although esophagoscopy has not been done again, as yet, size 50 F. mercury dilators have been passed and he has been completely free of symptoms.

This operation would seem reasonable for treatment of lower esophageal strictures, especially those of the esophagogastric junction.

Dr. Carl E. Lischer, St. Louis: Dr. Tom Burford and I have approached this problem in a slightly different manner. I have been very much interested in the discussion presented here this afternoon.

We have had 16 patients with esophagitis due to hiatal hernia and short esophagus, treated by Finney pyloroplasty without any attempt made to repair the hernia, without anything being done at the esophagogastric junction. The follow-up on the patients is of short duration, the longest being about 18 months, but so far the results have been highly satisfactory.

The 16 patients all have been relieved of their symptoms of heartburn and regurgitation and are able to sleep with comfort in a horizontal position. One patient developed stenosis at the esophagogastric junction. He had some ulceration at the time of original examination, and this has been relieved by dilatation. The others have marked symptomatic relief, and up to this time we are highly satisfied with this simple approach to a very complex problem.

It has the other advantage that if it fails on longer follow-up, some other procedure still can be done. We are reporting these cases at the

American Surgical Association meeting in April.

DR. F. HENRY ELLIS JR., Rochester, Minn.: I should like to thank the discussants for their remarks. As you can see, this is a complex problem; although I thought that most of the operative procedures currently in use had been covered in my review, I see that we already have new ones with which to deal.

I should like to discuss for just a moment the question of carrying out a gastric drainage procedure of some sort as treatment for this condition. Experimentally, at least, if any of the acid-secreting part of the stomach remains and there is an incompetent cardia, no matter whether pyloroplasty or gastroenterostomy is done, esophagitis is still likely to occur.

The results in our group of patients who underwent subtotal gastric resection suggest that the facilitation of gastric emptying may not be enough to cure these patients. In a significant number the obstruction was not relieved following this procedure. In addition, obstruction developed later in some, following healing of the ulcerative esophagitis.

I think that Dr. Adams' point about the possibility of carcinoma is an excellent one. This was an additional indication for surgical treatment in five of our patients. Ordinarily, one can tell on clinical grounds, particularly by esophagoscopy, whether carcinoma is present; but in five patients operation was carried out as much to eliminate the possibility of carcinoma as anything else.

I suspect, however, that, in most instances in which carcinoma of the esophagus is associated with a diaphragmatic hernia, the hernia is secondary to the carcinoma. One must assume that a hernia had been there for a long time and that carcinoma then developed. The carcinoma itself probably draws the stomach up into the thorax and produces the diaphragmatic hernia secondarily.

Again I would like to thank the discussants for their remarks.

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Richter's Hernia

Its Etiology, Recognition, and Management

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Richter's hernia is a deceptive entity with a high mortality which can be reduced by accurate diagnosis and early operation. Richter's hernia, or partial enterocele, is a protrusion of the antimesenteric surface of bowel wall into any abdominal hernia. It is deceptive because strangulation may occur early; frequently, in the absence of obstructive symptoms. The high mortality associated with this lesion has resulted from misdiagnosis and delayed operation.

Review of Material

A recent review of acute mechanical intestinal obstruction at this hospital indicated that 13% of the cases of incarcerated or strangulated hernia were of the Richter's type. The conflicting physical and roentgen findings and the mortality of 33% in this group stimulated further study.

We have had experience with 20 patients with Richter's hernia. The average age was 70 years; the youngest patient was 8 years of age, and the oldest, 90 years of age. Twelve of the patients were men; eight, women.

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From the Departments of Surgery, Wayne County General Hospital, Eloise, Mich., and the University of Nebraska College of Medicine. Formerly Chief Resident in Surgery (Capt. Gillespie), Assistant Director of Surgery (Dr. Glas), Resident in Surgery (Dr. Mertz), of the Wayne County General Hospital; Professor of Surgery (Dr. Musselman), University of Nebraska.

The femoral canal was the commonest site of herniation, present in 11 of our 20 cases. In this group six were men and five were women. The left side was involved in six patients and the right in five. Ventral hernias, incisional or umbilical, were the site of occurrence in five patients. Four patients were seen with a partial enterocele occurring in an inguinal hernia.

The clinical picture lacked uniformity. A tender palpable mass or tenderness over the site of a potential or recurrent hernia orifice was the most consistent physical finding, noted in 18 of 20 patients. Nausea and vomiting were present in 14 patients, with an average of two days from the onset of symptoms until the patient sought relief. Fecal vomiting in the absence of intestinal obstruction was observed in two patients. Abdominal distention was noted in eight patients. Three patients were observed with fluctuant inflammatory masses presenting at the site of femoral and incisional hernias. This represented perforation of the antimesenteric wall of the bowel in a Richter's hernia.

X-ray confirmation of small bowel obstruction was present in less than one-half of our cases. Negative flat plate examination of the abdomen was noted in two patients in the presence of nausea and vomiting and a palpable mass. A paralytic ileus was observed in one patient. X-rays were not obtained in three of our patients.

Herniorrhaphy without resection was carried out in eight patients in whom the bowel appeared viable. These patients made an uneventful recovery. Segmental resection with enteroenterostomy was carried out in four patients in whom strangulation had occurred. Enterostomy was necessary in three patients with enterocutaneous fistulas.

Simple inversion of a small area of necrosis was carried out in one patient with a successful result. Two patients were not operated upon, the diagnosis not being made until autopsy.

Six of our patients died. Two of these were from our group of seven patients in which evidence of obstruction was lacking and operation was delayed or omitted. Two patients died following segmental resection and enteroenterostomy. Operation was delayed 48 hours in one of these patients, and death occurred as a result of peritonitis and shock. The second patient died of aspiration pneumonia. Death occurred in two elderly patients following drainage of enterocutaneous fistulas. Both patients were in a debilitated state on admission with malnutrition, dehydration, and bronchopneumonia.

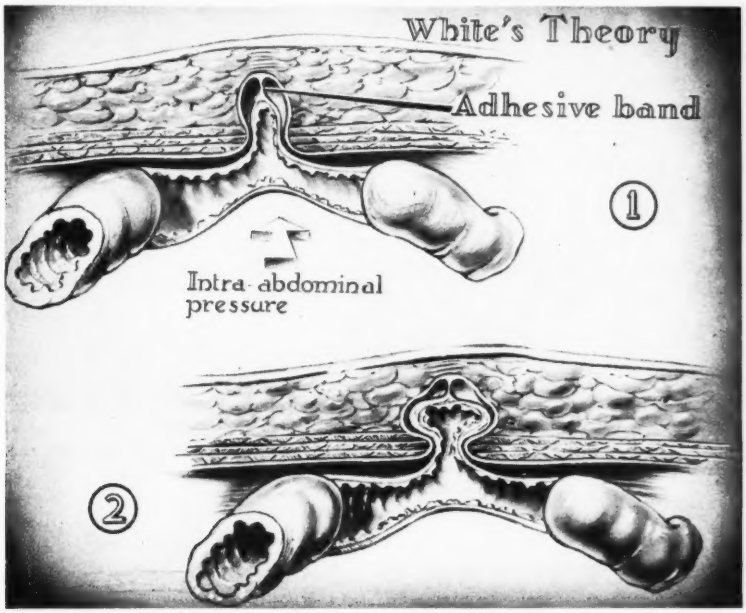

Fig. 1.—White's theory. Adhesive bands existing between the hernial sac and intestinal wall prevent complete reduction of the contents of the hernial sac.

Comment

Etiology

Interesting theories have been presented to explain the incarceration of the antimesenteric surface of the bowel wall in a hernial orifice.

One of the earliest theories, that proposed by White [1] in 1912, was that adhesive bands existed between the hernial sac and intestinal wall, preventing complete reduction of the contents of the hernial sac (Fig. 1). However, as he noted, bands and adhesions have been observed in less than one-half of the reported cases. An adhesive band between the femoral sac and ileum, preventing complete reduction of the ileum, was observed in one of our patients. It is possible that adhesive bands may be an important factor in cases of partial enterocele occurring in recurrent or incisional hernias.

Pressure variance between the intestine and hernial sac and alterations in intra-abdominal pressure have been proposed as etiologic factors.

A more acceptable theory has been presented recently by Orr,[2] who believes that partial obstruction may begin with incar-

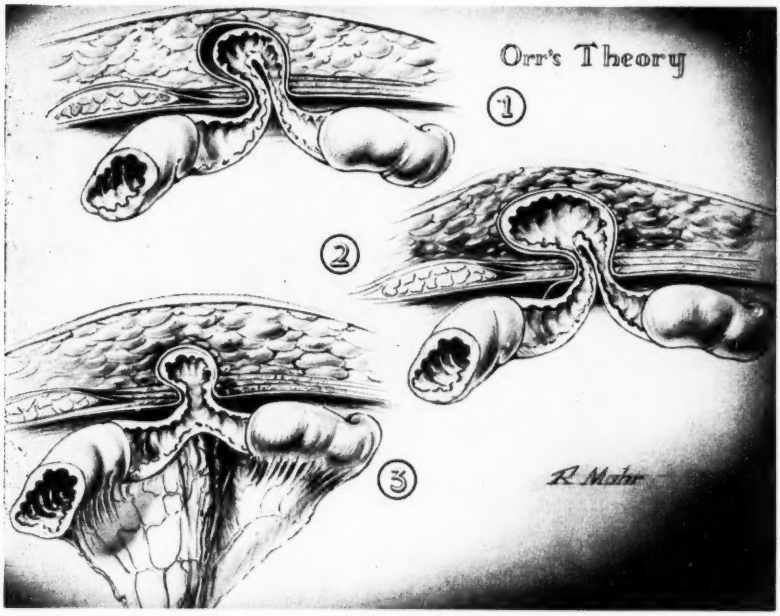

Fig. 2.—Orr's theory. Partial enterocele is initiated by incarceration, congestion, and edema of a loop of bowel. Increased peristaltic efforts with increased intraluminal pressure result in partial reduction of the intestinal wall.

ceration, congestion, and edema of a whole loop of bowel (Fig. 2). Increased peristaltic efforts with increased intraluminal pressure result in reduction of the mesenteric wall and restoration of bowel continuity, after which the intraluminal pressure is no longer effective in reducing the remaining incarcerated knuckle of bowel.

Pathology

The antimesenteric surface of the bowel is particularly prone to early strangulation because of the predominance of terminal arterioles. A pseudodiverticulum develops after incarceration as a result of congestion and edema and the propulsive efforts of the bowel.

Scarpa * has estimated that two-thirds constriction of the circumference of the bowel is necessary to produce complete proximal obstruction. Bissell [4] has disputed this and cites a case of fecal vomiting and small bowel obstruction with impairment of one-third of the circumference.

Usually partial enteroceles are confined to the ileum, but involvement of the jejunum and large intestine does occur.

Foltz [5] has stated that 90% of Richter's hernias are femoral in origin. Rhoades [6] cited three cases of partial enterocele occurring in incisional hernias and drew attention to the fact that this condition may be observed in any abdominal hernia.

Clinical Course

Previous reports have emphasized that the diagnosis of Richter's hernia based upon the clinical findings is impossible. We believe that cases of Richter's hernia may be divided into three groups based upon the clinical response:

(A) The Obstructive Group.—The symptomatology in this group is indicative of small bowel obstruction characterized by nausea and vomiting, cramping abdominal pain, distention, and an incarcerated hernial

* Scarpa, A., cited by Fowler.[3]

mass. Abdominal x-rays offer confirmatory evidence of small bowel obstruction. At operation a major constriction of the circumference of the bowel with impairment of the lumen is found.

The prognosis in this group is excellent, since early operation is clearly indicated in the presence of incarceration and small bowel obstruction.

The following case report illustrates the typical course of the obstructive group.

A 60-year-old white woman entered the hospital complaining of nausea and vomiting of three days' duration and a painful mass in the left groin.

Physical examination showed a tender mass 3 cm. in diameter below the left inguinal ligament. The abdomen was distended and tender to deep palpation. Increased bowel sounds were audible.

Flat plate examination of the abdomen demonstrated small bowel obstruction with "step ladder" pattern.

Operation 12 hours after admission revealed a strangulated partial enterocele in a femoral hernia. The hernia was reduced, and a resection of the involved segment with end-to-end anastomosis was carried out. The patient made an uneventful recovery and was discharged eight days later.

(*B*) *The Danger Group.*—The symptomatology in this group is vague and nonspecific. Nausea and vomiting are common; occasionally fecal vomiting is observed. Abdominal distention is rarely noted. A palpable mass in the absence of intestinal obstruction is frequently misdiagnosed as lymphadenitis. Paralytic ileus or a normal flat plate examination of the abdomen further clouds the clinical picture. The following case report illustrates clearly the difficulties encountered in this group.

A 69-year-old white man was admitted with complaints of nausea and vomiting of 12 hours' duration. Examination showed no evidence of abdominal distention. Bowel sounds were normal in character. Tenderness was noted over the right inguinal region; however, no mass was palpable.

Vomiting persisted and 48 hours later became fecal in character. Bowel sounds were decreased. Abdominal x-rays were obtained and showed gas present in the small and large intestine.

The patient's condition deteriorated as a result of hyperthermia, dehydration, and shock.

Operation was carried out three days after admission under local anesthesia. A femoral hernia was found containing a necrotic knuckle of terminal ileum. The bowel was freed from the hernial sac after an adhesive band had been divided. Segmental resection and enterostomy were then carried out.

The patient died 24 hours after operation with bilateral aspiration pneumonia.

The tragic result in this case occurred because operation was delayed while awaiting signs and symptoms of intestinal obstruction. Necrosis of the antimesenteric surface of the bowel without impairment of the lumen has been observed in nearly 35% of the reported cases. Two of our seven patients in this group died. Delay in operation is chiefly responsible for the high mortality in this group.

(*C*) *The Postnecrotic Group.*—Strangulation followed by enterocutaneous fistula has been observed in 15% of the reported cases. Nausea and vomiting, abdominal pain, and distention are noted early. Complete relief of the abdominal complaints with passage of gas and feces per rectum occurs in three to five days. A painful inflammatory mass appears 24 to 48 hours later. The following case report is typical of antimesenteric necrosis with enterocutaneous fistula.

A 62-year-old white man entered the hospital complaining of a reddened painful mass at the site of a right lower quadrant incisional hernia. The patient stated that the mass appeared three days before admission and enlarged steadily to the day of admission. On further questioning, the patient related a history of obstipation, abdominal distention, and cramping abdominal pain occurring four days prior to the onset of the hernial mass. The patient took liberal doses of cathartics, and regular bowel movements occurred 48 hours later. Examination of the abdomen showed a tender erythematous mass at the site of the right lower quadrant incisional hernia. The center of the mass was fluctuant and crepitus was noted.

Incision and drainage of the abscess was carried out on the day of admission. When the subcutaneous tissue was entered, a large amount of gas and fecal material escaped. At the inferior portion of the opening of the abdominal cavity a loop of bowel was found with perforation of the antimesenteric surface. Catheter drainage of the enterocutaneous fistula was then carried out.

Nine days following drainage of the abscess a celiotomy revealed a perforation 24 cm. from the ileocecal valve on the antimesenteric surface of the ileum. An ileotransverse colostomy was then

carried out. The patient made an uneventful recovery following the second operation.

The prognosis in this group is excellent since the obstruction is relieved and generalized peritonitis is averted by enterocutaneous fistula formation.

The diagnosis in each case must remain presumptive until clearly established at operation. The prime consideration is, however, early operation when confronted with a small painful mass or localized tenderness over a potential hernial orifice, without respect to the presence or absence of intestinal obstruction.

Treatment

Treatment of strangulation requires segmental resection with end-to-end anastomosis. Poor-risk patients may be managed by a Mikulicz resection or enterostomy through the necrotic area. If the area of strangulation is small, it may be conveniently managed by plication or inversion with interrupted Lembert sutures.

The experiences of Cattell,[7] Togni,[8] and Wilson[9] support the rule regarding strangulation: "When in doubt, resect." Each author reported a case of perforation, peritonitis, and death occurring several days after operation at the point of incarceration.

Neuhof[10] advocates a transperitoneal approach in cases of suspected strangulation, reasoning that reduction frequently occurs before the sac is entered and resection is more easily carried out by celiotomy.

Summary

We have reviewed 20 cases of Richter's hernia. Nausea and vomiting accompanied by a palpable tender mass or localized tenderness over a potential hernial orifice were the commonest clinical findings. X-ray evidence of obstruction was found in less than one-half of the cases. Partial enterocele may be manifested by small bowel obstruction, nausea, and vomiting in the absence of intestinal obstruction, or fecal fistula formation. The mortality is highest when the continuity of the bowel is undisturbed, the lesion is not recognized, and operation is delayed. Treatment consists of early operation and resection of the devitalized segment with end-to-end anastomosis and herniorrhaphy.

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Inguinal Hernia in Children

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and
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The frequency of occurrence of bilateral inguinal hernia in children in the first seven years of life is the subject of this study. Ninety consecutive cases of inguinal hernia have been personally operated upon by us. All of these children have had bilateral exploration of the inguinal canals, and we are reporting upon the frequency with which an unsuspected inguinal hernia or a patent processus vaginalis is found in patients presenting with unilateral hernia.

In this series of 90 cases, 10 of the patients were girls. Two were first seen with bilateral hernias, and eight with unilateral hernias. Of the eight, four had a right- and four a left-sided defect. At operation, three of these girls were found to have an unsuspected hernia on the opposite side. Thus, approximately 40% of the girls with unilateral hernia in this series subsequently were shown to have a hernia in the apparently uninvolved side (Table 1).

In this series 80 of the patients were boys, and in addition to presenting the group as a whole, we have divided this group into two subgroups: (1) those patients under 12 months of age and (2) those from 1 through 6 years.

Of those boys under the age of one year (38 cases), 8 had bilateral hernias when first seen, 6 had a left inguinal hernia, and 24 had a right inguinal hernia. All 6 patients with left hernias were found to have bilateral involvement (100%), whereas 14 of the 24 patients first seen with a right-sided hernia were found to have bilateral defects (55%).

Of those boys from 1 through 6 years of age (42 cases), 5 had bilateral hernias when first seen, 10 had a left inguinal hernia, and 27 had a right inguinal hernia. Of the 10 boys with a left hernia, 7 were found to have bilateral defects (70%), whereas 15 of the 27 patients first seen with a right-sided hernia were found to have bilateral defects (55%, Table 2).

TABLE 1.—*Incidence of Unsuspected Hernia in Ten Girls* Discovered at Operation for Inguinal Hernia*

Age, in Yr.	No. of Cases	Initial Examination		Operative Examination	
0-1	4	Left	2	Bilateral	1
		Right	2	Bilateral	1
1-6	6	Left	2	Bilateral	1
		Right	2	Bilateral	0
		Bilateral	2	Bilateral	2

* Of 10 girls, 8 (80%) had unilateral hernia when first seen, and 3 of these 8 (40%) had unsuspected hernia discovered at operation.

TABLE 2.—*Incidence of Unsuspected Hernia in Eighty Boys* Discovered at Operation for Inguinal Hernia*

Age, in Yr.	No. of Cases	Initial Examination		Operative Examination	
0-1	38	Left	6	Bilateral	6 (100%)
		Right	24	Bilateral	14 (55%)
		Bilateral	8	Bilateral	8
1-6	42	Left	10	Bilateral	7 (70%)
		Right	27	Bilateral	15 (55%)
		Bilateral	5	Bilateral	5

* Of 67 boys presenting with unilateral hernia, 42 were found to have bilateral defects (65%). Of the 16 presenting with left hernia, 13 (80%) were bilateral; of the 51 presenting with right hernia, 29 (60%) were bilateral.

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Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 24, 1956.

From the Department of Surgery, Washington University School of Medicine, and the Barnes and St. Louis Children's Hospitals. Dr. Mueller's present address: Chairman, Department of Surgery, State University of New York College of Medicine, Syracuse, N. Y.

As is apparent from the foregoing paragraphs, the incidence of unsuspected hernias is not markedly different in the two age groups. This is in general agreement with the findings of Rothenberg and Barnett,[1] who found that in a series of 12 children under the age of one year all had bilateral hernias. The incidence of unsuspected hernias in 38 children ranging in age from 1 to 12 years was 70%, and there was no great difference in the occurrence of unsuspected hernia between right and left. Gross,[2] on the other hand, states that for a time he performed bilateral inguinal exploration but found a hernia on the unsuspected side less than half the time, and abandoned the procedure.

This group of cases admittedly represents a selected group, since the proportion of infants under one year of age seems to be very high in comparison with other reported series.* All of these patients have been referred by pediatricians in the St. Louis area, and we believe that these specialists are prone to recommend early surgical repair since it has proved to be a safe and effective procedure. The surgical procedure utilized in these cases consists of incision of the external oblique aponeurosis and cremaster muscle without disturbance of the spermatic cord from its bed in the inguinal canal. After dissection and high ligation of the sac are performed, the cremaster, external oblique, and Scarpa's fascia are reapproximated with interrupted fine silk sutures. No attempt is made to repair any defect in the abdominal wall.

We believe that this series is too small to be of significance in reporting the incidence of incarceration, the relative occurrence of left and right hernias, or the association of hydroceles and undescended testes. We do believe, however, that the incidence of an unsuspected hernia or a patent processus vaginalis is sufficient to warrant bilateral exploration, since this procedure carries little added risk and contributes nothing to the period of convalescence.

We recommend that exploration of both inguinal canals be performed in all children under the age of 7 years who are treated for inguinal hernia, since the incidence of an unsuspected hernia or potential hernia is approximately 65%.

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DISCUSSION

On Papers by Capt. Gillespie, Drs. Glas, Mertz, and Musselman; and Mueller and Rader

Dr. Chester B. McVay, Yankton, S. D.: Our experience so closely parallels that presented in this excellent paper by Capt. Gillespie and Drs. Glas, Mertz, and Musselman that we really have very little to add. I think that their accumulation of so many cases is remarkable.

We have nine cases in our series—five femoral, one inguinal, one incisional, and one obdurator. There was one case of a fecal fistula of 10 days' duration, and one patient moribund upon arrival at the hospital with a femoral Richter's hernia.

We had one inguinal and one femoral Richter's that were quite interesting. Both were in people over 80 years of age, with no detectable hernia, no previous abdominal incisions, and intermittent episodes of partial intestinal obstruction over a period of several years.

Finally it was serious enough to bring them to the hospital. The diagnosis in the femoral case was made only at operation for intestinal obstruction. The other was an 85-year-old, 80-lb. (36 kg.) woman with no detectable hernia, in very poor physical condition, with an incomplete obstruction but with sufficient symptoms to warrant intubation.

[Slide] This led us to make a tentative diagnosis of a Richter's hernia preoperatively. This had considerable value in this patient because of her pre-

carious physical condition and allowed us to approach the point of obstruction under local anesthesia very simply with repair of the hernia from within.

This shows the Cantor tube in place, with a small amount of barium injected through it, and the ballooning of the obstruction in the left inguinal region.

Those with a presenting hernia we have repaired by the route usually used for repairing an inguinal hernia. In those operated upon primarily for intestinal obstruction, the hernia has been very simply repaired from within, with one or two sutures.

I think it is worth calling attention to the fact that in the absence of surgical scars recurrent bouts of intestinal obstruction should bring to mind a Richter's type of hernia.

The proposition presented in the paper by Drs. Mueller and Rader is certainly interesting. In general, through the years we have followed pretty much the teaching of Gross and have done bilateral hernias only if they were present and also, of course, if there was a history of a bulge on the opposite side. Our statistics very closely parallel those of Drs. Mueller and Rader. I will not repeat them except to say that our incidence of bilateral herniation in children under 6 was 13%.

An interesting comparison here is that the overall incidence of bilateral herniation in all age groups in our series of 500 hernias was 14.3% and additive to this group there were 6% who had had a previous hernia operation on the opposite side, or who subsequently returned to have a hernia repair on the opposite side. This is the only figure I can give on the incidence of later bilateral herniation.

What, then, happens to these incipient hernial sacs that do not actually develop into a hernia? It is impossible to state, of course. I do have one report by Dr. B. J. Anson, in 1942, appearing in the *Quarterly Bulletin of the Northwestern University Medical School* in which the inguinal regions of 100 cadavers were examined before the peritoneum was removed. In that group, 20% had some remnant of a processus vaginalis without a hernia.

A number of years ago we were thinking along these lines, but something happened that changed our direction of thought—a very disquieting experience five years ago. We repaired simple bilateral indirect hernias in a 2-month-old infant by our method of "abdominal ring repair," only to have the patient return in three weeks with bilateral femoral hernias. Since then, rather than directing our attention to bilateral herniotomy we have carefully explored the inguinal region whenever repairing a hernia in an infant. Of course, one must be careful of the very delicate tissue. This has resulted in finding one 2-month-old infant with a direct hernia which we otherwise would have missed.

Therefore, for the past five years we have carefully examined the inguinofemoral regions in hernias in infants to rule out associated hernias. Occasional findings like that might hardly seem to warrant such an exploration, but it takes only one or two such oversights to ruin one's series of successful hernia operations.

This procedure usually takes very little extra time. It certainly does not weigh against exploring the opposite side. However, we believe that the time taken to explore the inguinal region does not justify our exploration of the opposite side.

DR. ROBERT M. WANSBROUGH, Toronto, Canada: I am very much interested in this subject. In the hospital with which I am associated, for many years we have been averaging a little better than 500 hernias a year in children, and for 20 years at least, and nearly always for 10 years before that, with hernia in the inguinal canal the opposite side was explored.

We believe that looking into the opposite side takes only a minute or two, and we are certain that the little folk won't be coming back. The only exception is when we have to operate on very small children. That is when we get recurrences, and we do get them, although not many. Anyone who has been doing a great number of hernia operations will have recurrences, especially in very small children.

There is another thing, the hereditary incidence. A great number of my patients are the children of girls or boys on whom I operated to repair hernias 20 or 25 years ago. There is a very marked hereditary incidence in hernias. We have a rough statement that if you see a child with a left-sided hernia, over 40% of these cases of left hernias will have right hernias, and I believe those are practically the same figures quoted here. Nearly all girls have bilateral sacs.

I noticed that there was no mention made of trusses. We had a memo from the Hospital the other day, saying that they had $1100 worth of trusses and not one had been asked for since 1952, which was a pleasure to me because it saves the children from coming in with strangulation.

I heartily agree with Dr. Mueller when he states that you should always explore the opposite side except in the very small child, on whom one operation is quite enough, and in that case you are not apt to get a recurrence.

Choledochoduodenal Fistula Complicating Duodenal Ulcer

A Report of Five Cases and Review of the Literature

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and
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Internal biliary fistulae are one of the more uncommon diseases affecting the upper gastrointestinal tract. Most fistulae are secondary to gallbladder disease and are almost always symptomatic. Clinically, however, the most silent internal biliary fistulae are choledochoduodenal in nature, especially where secondary to penetrating duodenal ulcer. The surgical management of this condition enjoys widespread variation in the literature, undoubtedly owing to the sparsity of cases available for study. It is entirely probable that large numbers of such cases and their complications are undiagnosed yet treated for the underlying peptic ulcer disease.

The incidence of spontaneous internal biliary fistulae is reported in the following Tabulation:

From Autopsy Material			Encountered During Biliary Tract Surgery		
Davison & Aries	0.1%	(6,000)	Dean	1.2%	(1,263)
Borman & Rigler	0.2%	(30,000)	Bernhard	1.8%	(2,417)
Roth, Schroeder, & Schloth	0.5%	(10,866)	Puestow	3.2%	(500)
			Kehr*	5.0%	(2,000)

Choledochoduodenal fistulae represent approximately 10% to 20% of all spontaneous internal biliary fistulae (Waggoner and LeMone; Garland and Brown, and others), and approximately 80% of the choledochoduodenal fistulae are secondary to penetrating duodenal ulcer.

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Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 24, 1956.

* Cited by Borman and Rigler.

A review of the records from the Veterans Administration Hospital, Hines, Ill., from 1951 to 1956, revealed five cases of choledochoduodenal fistula secondary to duodenal ulcer. An extensive review of the American literature dating from the first report of barium visualization of the biliary tree by Hunt and Herbst,† in 1915, reveals 23 case reports, although a few other instances of choledochoduodenal fistulae have been mentioned without any case report. We have tabulated all of these cases. The diagnosis of our cases and those cases collected from the literature was based on an adequate history of peptic ulcer coupled with at least one of the following two criteria: (1) x-ray visualization of a choledochoduodenal fistula with ulcer deformity of the duodenum; (2) operative or autopsy findings of a choledochoduodenal fistula associated with a duodenal ulcer.

Report of Cases

The following are the five new cases which we wish to present:

CASE 1.—A 34-year-old white man was admitted to the hospital because of hematemesis and melena of one day's duration. His past history revealed he had had cramping upper abdominal pain at intervals for one and one-half years. A barium meal one and one-half years previously had revealed a duodenal ulcer, and the patient had had good relief from antacids. At no time in his life had he had jaundice or selective dyspepsia for fatty foods. No fever or chills preceded the present episode. Physical examination was noncontributory. Laboratory tests showed a moderate

† Cited by Borman and Rigler.

Fig. 1 (Case 1).—Common duct fistula, with visualization of the cystic duct and right and left hepatic ducts.

anemia, and liver-function studies were within normal limits. An upper gastrointestinal series revealed a duodenal ulcer with a fistula into the common duct. Surgical exploration revealed a duodenal ulcer and a somewhat dilated common bile duct with a normal gallbladder and a normal-sized cystic duct. After the duodenum was transected at the pylorus, the common duct was opened; attempts to pass a probe into the duodenum were unsuccessful. However, the probe could be passed through the fistula into the duodenum. A 70% gastric resection with a retrocolic Polya anastomosis was performed. A T-tube was placed in the common duct, and a cholecystoduodenostomy was done. Postoperative course was uneventful; follow-up examinations at three, six, and nine months revealed no history suggestive of cholangitis, and the patient has been symptom-free.

Comment.—It is to be noted in this case that it was impossible to pass a probe distally through the ampulla, owing to the inflammatory reaction causing distal common duct obstruction.

CASE 2.—An 85-year-old white man was first admitted to Hines Hospital in December, 1953, for perforated peptic ulcer (x-ray demonstrated free air) and was treated conservatively, with good response. Subsequent gastrointestinal series showed 20% gastric retention and deformed duodenal bulb. He was relatively well except for 500-1000 cc. nightly gastric aspiration until June, 1955, when patient was admitted with a nine-day history of upper abdominal pain and fever without chills. Examination of the right lower posterior chest revealed dullness with decreased tactile fremitus and breath sounds to D-6 level. (A Grade 2 systolic murmur was also present.) Temperature, 100 F; pulse rate, 112. The laboratory data showed mild anemia, leucocytosis, and A/G ratio of 2.3/3.6 gm., NPN 44 mg., and free acid 36 units. Subsequently, the patient was operated upon, and a right subphrenic abscess was drained by resection of the 12th rib. It was felt that the etiology of this abscess dated back to his previous perforation. Upper gastrointestinal series showed a duodenal bulb deformity and choledochoduodenal

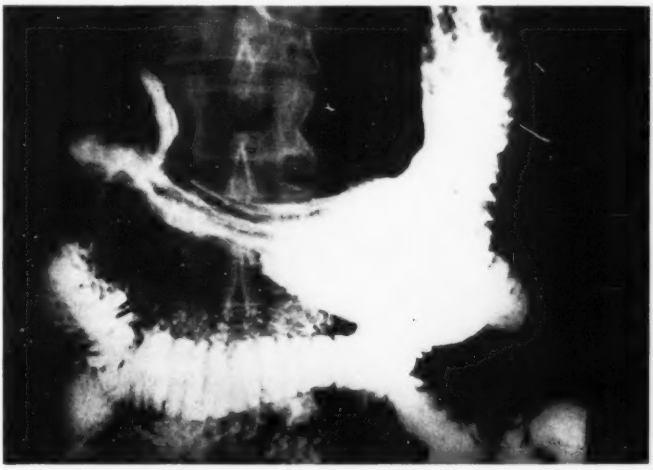

Fig. 2 (Case 2).—Common duct fistula. The fistula was first observed in this case when air was seen in the biliary tree on a scout film of the abdomen.

fistula, with 75% gastric retention at three hours. During ulcer therapy the patient's pyloric obstruction became almost complete, and, therefore, a gastroenterostomy was done under local analgesia. The postoperative course was uneventful, with progressive improvement. The patient was discharged on ulcer management, and reexamination at a nine-month interval revealed a 20 lb. weight gain and no other complaints. A repeat upper gastrointestinal series revealed a well-functioning gastroenterostomy, with no evidence of choledochoduodenal fistula.

Comment.—A minimal procedure was done on this patient because of his poor general condition and age (85 years). However, his recovery and response have been more than satisfactory.

CASE 3.—A 33-year-old white man had had peptic ulcer symptoms since 1944 and a history of massive upper gastrointestinal hemorrhage in 1952 necessitating transfusion of 3000 cc. of blood. At that time, x-rays showed an ulcer deformity of the duodenum. The patient was admitted to Hines Hospital in August, 1955, complaining of epigastric and right upper quadrant pain with a 20 lb. weight loss (no chills or fever). Physical examination revealed epigastric and right upper quadrant tenderness and no palpable abdominal organs. The hemogram was normal; the serum bilirubin was 0.8 mg. per 100 cc., and alkaline phosphatase was 2.7 mg. per 100 cc. Two upper gastrointestinal series at a one-month interval showed a persistent choledochoduodenal fistula and a duodenal ulcer. On Sept. 1, 1955, at surgery, scarring was present in the duodenum which extended into the gastrohepatic ligament. Exploration through the duodenal stump revealed a low-lying posterior wall ulcer at the site of fistula formation. A 75% Billroth II antecolic Hoffmeister resection was done. A choledochostomy was performed, and it was impossible to pass a probe through the distal common duct. Therefore, an anastomosis of the gallbladder to the duodenal stump was also performed. Postoperative intravenous cholangiogram revealed a functioning cholecystoduodenostomy. At present writing, the patient has gained weight and is asymptomatic.

Fig. 3 (Case 3).—Marked duodenal deformity (11-year history of duodenal ulcer), with choledochoduodenal fistula.

Comment.—It is again noted that the distal common duct was obstructed as a result of the inflammatory process.

CASE 4.—A 57-year-old white man was admitted to the hospital in May, 1955, because of intermittent vomiting of one week's duration. His past history revealed recurrent episodes of active duodenal ulcer, proved by x-ray since 1942. Two years prior to this admission the patient had had a moderately severe gastrointestinal hemorrhage thought to be due to an active duodenal ulcer shown by x-ray. Except for moderate epigastric tenderness, the results of physical examination were essentially normal. Liver-function tests were within normal range, as were all other routine laboratory tests. The first upper gastrointestinal series revealed complete pyloric obstruction, and a repeat examination 10 days later, after strict ulcer management, revealed a markedly deformed duodenal bulb with a choledochoduodenal fistula. At this time, the patient left the hospital, against medical advice. No follow-up examinations have been made since then.

Comment.—Surgery was advised for this patient, but it was refused. The patient was lost to follow-up examination, having signed out of the hospital against medical advice.

CASE 5.—A 55-year-old white man was admitted to the hospital because of right upper quadrant pain. The patient had a history of intermittent episodes of epigastric pain, usually occurring about three hours after meals and awakening him at night, since 1921. This pain had always been relieved promptly by milk or antacids. In the six months prior to admission the pain had shifted to the right upper quadrant and penetrated straight through to the back. He had also developed a selective dyspepsia for fatty foods over the same

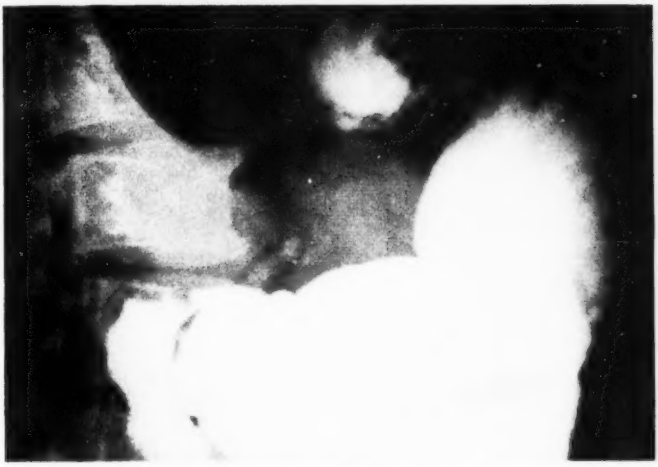

Fig. 4 (Case 4).—This patient was initially found to have complete pyloric obstruction, with no visualization of the common duct fistula. However, on strict ulcer management, a repeat upper gastrointestinal series revealed the fistula, along with a large, dilated stomach.

interval of time. At no time had he been jaundiced or had any chills or fever. Physical examination was noncontributory except that the liver could be felt 2 fingerbreadths below the right costal margin. All liver-function studies were normal except for a sulfobromophthalein (BSP) retention of 34%. All other laboratory tests were normal. However, an upper gastrointestinal series and cholecystogram revealed nonvisualization of the gallbladder and a deformed duodenal bulb with barium extending into the biliary tree by way of the common bile duct. The patient was markedly relieved of his symptoms on a strict ulcer regimen. He was taken to surgery in November, 1951, at which time he was found to have marked inflammation and induration of the duodenum near the common duct. This area was thought to be the fistulous tract with its origin in a duodenal ulcer. Cholelithiasis was also found, and a cholecystectomy was performed at this time. Postoperatively, the patient had a recurrence of his right upper quadrant pain which was relieved by strict ulcer management. He was seen on follow-up examination at the end of three months, and he still complained of right upper quadrant pain which was relieved by antacids. X-rays at this time revealed the persistence of a choledochoduodenal fistula. No liver-function studies were done. Shortly thereafter, this patient was lost to follow-up examinations.

Fig. 5 (Case 5).—This barium study reveals a marked duodenal deformity with common duct fistula. Even though this patient was found to have cholelithiasis, this x-ray reveals normal-sized cystic and common ducts.

Comment.—This case is the only one in which there was associated gallbladder disease. Roentgenographically, duodenal ulcer was demonstrated. Moreover, at the time

of surgery, the common duct and duodenum were bound together in an inflammatory mass which, clinically, was believed to be due to duodenal ulcer.

General Comment

A review of all 28 cases reveals the average age to be 45 years, the youngest being 24 years and the oldest, 85 years. The duration of peptic ulcer history averaged 11.1 years. It is interesting to note that all reported cases have occurred in men. Roentgenographically demonstrable choledochoduodenal fistula was reported in every case. There is no common symptomatology that would lead one clinically to the diagnosis of

*Choledochoduodenal Fistula Complicating Duodenal Ulcer**

Authors	Case	Age	Race	Sex	Duration, Yr.	Symptoms	Treatment	Follow-Up
1 Stephenson (1921)	A.V.A.	56	.....	M	18	Epigastric pain	Conservative med. management	1 yr.; CDF‡ still present
2 Kantor & Jaffin (1928)	8	29	.....	M	7	Epigastric pain; hematemesis	Conservative med. management	1 yr.; death "acute abd."
3 Sickels & Hudson (1934)	1	51	W	M	1½	Vomiting; wt. loss; pain	Conservative med. management	No complaints
4 Garland & Brown (1942)	1	45	W	M	8	Epigastric pain	None	None
5	2	34	W	M	6	Epigastric pain	Billroth II	None
6 Weinberger & Rosenthal (1945)	1	32	W	M	6	Epigastric pain	None; Army selectee rejected from service	
7 Waggoner & LeMone (1949)	E.B.	71	W	M	½	Epigastric pain	Exp. lap., no def. surgery	3 mo.; healed CDF & ulcer
8 Barth & Cannon (1949)	J.M.	29	.....	M	6	Epigastric pain	Billroth II	None
9 Wollgast & Stampfli (1951)	1	32	.....	M	14	Epigastric pain	Billroth II	3 yr.; no complaints
10 Sullivan & Hamman (1951)	1	27	W	M	10	Epigastric pain; hematemesis	Billroth II	None
11 Martin (1952)	U.V.D.	42	W	M	11	Pyloric obst.; wt. loss	Billroth II	Weight gain
12 Tate & Shaw (1952)	K.W.	28	W	M	2½	Pain; wt. loss; anemia	Billroth II; fistulectomy; cholecysto-duodenostomy	6 mo.; asymptomatic
13 Yon & Bell (1953)	C.S.	57	N	M	½	Epigastric pain	Billroth II; transplantation of fist. into lower duodenum	6 mo.; no complaints
14 Cogbill & Roth (1953)	R.T.	34	W	M	5	Epigastric pain	Billroth II; choledochostomy	1 yr.; no complaints
15	L.J.S.	52	W	M	4	Periumbilical pain	Cholecystectomy; g.e. and vag.; choledochostomy	18 mo.; pain recurrent; x-rays normal
16 Walker & Large (1954)	W.C.	56	W	M	20	G.I. hemorrhage	Billroth II; also early ca. stomach	3½ yr.; died of ca. larynx
17	C.W.	49	W	M	8	Pain; vomiting; "clay" stools	Billroth II; fist. cannulated & transplanted to duod.	6 mo.; no complaints

* A review of all case reports from the American literature and addition of five cases.

*Choledochoduodenal Fistula Complicating Duodenal Ulcer**—Continued

Authors	Case	Age	Race	Sex	Duration	Symptoms	Treatment	Follow-up
18 Craighead & St. Raymond (1954)	W.L.	50	W	M	38	Epigastric pain; wt. loss	Resect panc. head; modified Whipple	Death; p.o. III; peritonitis; hemorrhage
19	R.G.	45	W	M	15	Epigastric pain	Med. management, op. contemplated	Has had CDF on x-ray for 2 yr.
20	S.W.	49	N	M	10	Pyloric obst.; weight loss	Billroth II	Marginal ulcer 6 mo. p.o.
21	P.B.	24	W	M	17	Acute pain; vomiting	Billroth II; cholecystoduodenostomy	6 mo.; occasional dyspepsia
22	A. McG.	63	W	M	30	Obstructive symptoms; pain	Bancroft-exclusion of ulcer and fistula; 3 mo. later Roux-Y choledochojejunostomy, distal C.D. obstruction	
23 Macumber & Stoll (1954)	R.L.	54	W	M	16	Pain; pyloric obstruction	Bancroft mod. of Billroth II	None
24 Hutchings, Wheeler & Puestow (1956)	1	34	W	M	1½	Epigastric pain; hematemesis, 1955	Billroth II; choledochostomy; cholecystoduodenostomy	6 mo.; 7 lb. wt. gain; x-rays negative; no complaints
25	2	85	W	M	2	Fever; RUQ pain; pyloric obst., 1955	I &D Rt. subphrenic abscess; gastroenterostomy under local anesthesia	9 mo.; 20 lb. wt. gain functioning gastroenterostomy
26	3	33	W	M	11	Epigastric & RUQ pain; 20 lb. wt. loss, 1955	Billroth II; choledochostomy; cholecystoduodenostomy	6 mo.; 11 lb. wt. gain; no complaints
27	4	57	W	M	13	Nausea & vomiting	Placed on ulcer management; left hospital against medical advice	None
28	5	55	W	M	30	RUQ & epigastric pain	Cholecystectomy, 1951	Recurrent symptoms; relief from antacids, 1952; lost to follow-up
29†	6	47	W	M	6	RUQ & rt. flank pain	Billroth II; choledochostomy	

† Addendum: This case was operated on two days prior to submission of this article for publication. X-ray examination was not conclusive, but at surgery a choledochoduodenal fistula was found opening into a duodenal ulcer 1.5 cm. above the ampulla of Vater. Distal common duct narrowing was present.
‡CDF, choledochoduodenal fistula.

choledochoduodenal fistula. The symptoms in almost all cases are those of the underlying primary disease, e. g., penetrating duodenal ulcer showing the usual complications of unremittent pain, obstruction, or hemorrhage. Contrary to the high incidence of ascending cholangitis attendant upon other types of spontaneous internal biliary fistulae, it is a relatively rare component of the clinical picture associated with choledochoduodenal fistula secondary to duodenal ulcer.

The early cases reviewed in this series were treated medically, with equivocal results; one died in one year with an acute abdominal condition; one showed the fistula still present after one year on conservative management, and one had no complaints. It is interesting to note that in three cases, in which subsequent x-rays were taken, the choledochoduodenal fistula was still present after one to three years of medical management. One might well deduce from this observation the possibility that distal common duct scarring and occlusion had oc-

curred, causing the fistula to remain open as the only exit for drainage of the biliary tree. Most authors advocate a Billroth II type of gastric resection, with or without the Bancroft modification, depending upon the location of the ulcer in the duodenum. In conjunction with this, however, various authors have recommended Roux-en-Y choledochojejunal anastomosis, with excision of the fistulous tract; choledochoduodenostomy, and cholecystoduodenostomy.

Therapy of this disease must be directed with three objectives in mind. These are (1) healing of the duodenal ulcer, (2) preventing regurgitation of gastrointestinal contents into the biliary tree, and (3) reestablishing normal biliary tract continuity if possible. The first two objectives are most readily accomplished by subtotal gastric resection, Billroth II operation, with or without the Bancroft modification, as previously stated. This is, therefore, by necessity of the proximity of the fistula, done as an ulcer exclusion operation. One must add, however, that massive upper gastrointestinal hemorrhage, necessitating emergency surgery, could not, of course, be handled in this manner. The final objective of therapy should be determined by choledochostomy, thus establishing patency or occlusion of the common duct distal to the entrance of the fistula. If it is patent, T-tube drainage of the common duct with subsequent postoperative cholangiograms would be sufficient. If occluded, an alternate means of internal biliary drainage is deemed advisable. In Case 17 and in two of our cases, Cases 24 and 26, distal common duct obstruction was present and cholecystoduodenostomy was performed. Likewise, if the inflammatory process is so extensive as to preclude choledochostomy, cholecystoduodenostomy would be advisable. Case 22 illustrates this point. A Bancroft operation was performed, and three months after operation the patient developed chills, fever, and jaundice. At surgery, a scarred obstructed distal common duct was found. A Roux-en-Y choledochojejunostomy was done, since a cholecystectomy had been performed 24 years previously.

Conclusions

A review of 23 case reports of choledochoduodenal fistulae complicating duodenal ulcer from the American literature and an additional 5 cases from Hines Hospital have been presented. This disease is relatively rare, but undoubtedly much commoner than herein reported. The symptomatology is nonspecific and cannot be distinguished from the underlying primary ulcer pathology. The possibility of encountering biliary fistulae must be kept in mind when gastric surgery is performed. Surgical therapy is the indicated treatment of this complication of duodenal ulcer, and subtotal gastric resection, Billroth II type, is definitely indicated. Exploration of the common duct, and, if it is distally obstructed, performance of a cholecystoduodenostomy are recommended.

Summary

Five cases of choledochoduodenal fistula complicating duodenal ulcer are presented.

A review of the American literature and tabulation of 23 case reports is included.

A survey of the symptomatology suggested no features distinguishable from those of the underlying ulcer disease.

Cholangitis or evidence of liver damage was not a feature of this disease complex.

A Billroth II type of subtotal gastric resection and choledochostomy with possible cholecystoduodenostomy comprise the treatment of choice.

25 E. Washington St. (2) (Dr. Puestow).

DISCUSSION

DR. ALFRED M. LARGE, Detroit: We have had four of these cases in the hospitals of the Wayne University College of Medicine in recent years, three of which have been reported previously. I should like to comment upon them and to emphasize, if I may, one or two points that have been brought out by Dr. Hutchings.

First, these cases surely are uncommon, but I think it is certainly true that, when they do occur,

they are almost always associated with duodenal ulcer, and not with gallstones.

The second point is that these complicated ulcers can be well treated, I think, by an exclusion type of gastric resection, that is, by removal of an appropriate part of the stomach and part of the duodenum, leaving the ulcer in place.

All four cases we have seen have been treated by this method. One of the patients had had a previous history of recurring bouts of jaundice associated with regurgitation cholangitis, but all four cases were treated by resection without any disturbance of the fistulous tract, and all four did well.

The longest follow-up is for a period of four years, and the two patients who have been followed for that length of time have continued to do well. So, in general, I think, when these cases are seen, it may be possible to simply perform a standard gastric resection without the necessity of doing anything to the common duct itself.

DR. JAMES R. WHEELER, Hines, Ill.: Just two days ago we added our sixth case to this series. The patient was a 47-year-old white man who had been followed for two years, because of persistent pain that was believed to be due to a duodenal ulcer in the second portion of the duodenum. X-rays, however, had not demonstrated a choledochoduodenal fistula.

At the time of surgery, because of the marked induration of the common duct, we felt that exploration of the common duct was indicated. Probing of the common duct revealed obstruction at the level of the duodenal ulcer. When the common duct was irrigated with isotonic saline, a jet of saline solution was seen to be coming from the base of the ulcer. It was possible to pass a soft rubber catheter down through the common duct and out through the ampulla of Vater, and by this means a long-limbed T-tube was placed in the common duct. The duodenum was then closed around a large catheter. A subtotal gastric resection was performed, and a posterior colic Polya anastomosis was accomplished.

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Observations on Venous Thrombosis

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and
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Over the past few years we have published several papers on the different facets of venous thrombosis.* We believe that the observations made in these papers are still valid and perhaps are worth bringing together.

Pulmonary embolism is an important factor in postoperative deaths. Over the years, deaths after operation due to shock, hemorrhage, sepsis, dehydration, and chemical imbalance have decreased, but not those due to pulmonary emboli. After gastrectomy pulmonary embolism accounts for 25% of the deaths.

Material and Methods

The incidence of venous thrombosis with or without pulmonary embolism is hard to assess since a clinical diagnosis of intravenous clotting is extremely difficult to make. Our observations are based on the actual demonstration of a thrombus at autopsy by dissecting the veins of the pelvis and the lower extremities. The technique in brief consists of the removal and examination of the veins on each side, from the lower end of the inferior vena cava to the posterior tibial vein at the level of the internal malleolus. These dissections were carried out at autopsy on 165 middle-aged or elderly male patients at Westminster Hospital, London. The pathologic findings were recorded, then confirmed by microscopic study. These findings were then compared with the appropriate clinical and biochemical data, which had been obtained independently.

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*References 1, 2, and 3.

Observations

We were impressed by the finding that 73% of the venous thrombi arose from the large veins of the pelvis and thigh and not in the small veins of the calf and foot, as reported by others. We strongly refute the statement that thrombi do not occur in the superficial femoral vein, unless they are an extension of a primary process from the calf veins. Perhaps our failure, clinically, to diagnose venous thrombosis in the past has been because too much attention has been focused on the calf veins rather than on the thigh veins.

Superficial femoral vein ligation as a prophylactic or therapeutic measure against pulmonary embolism is likely to be ineffective, because 49% of our series were initiated above this point. The patient who appears to have thrombophlebitis is far from secure against the danger of pulmonary embolism. On four occasions in our series embolism resulted from an inflammatory thrombus. We believe that these people can produce an embolus either from the free-floating central head of the thrombophlebitic mass or from the frequently associated bland thrombus in the opposite extremity. The clinical differentiation of phlebothrombosis from thrombophlebitis, on the basis of embolic potential, is dangerous.

It is now 100 years since Brucke considered that alterations in the vein wall, from which thromboplastic substances might be liberated, were factors in the precipitation of venous thrombi. We have attempted to examine the underlying vein wall for any changes by carrying out serial section of the thrombus and the vein wall in 21 incipient thrombi. Our results

were very conclusive that the local injury or diseases of the vein wall, as studied by ordinary staining techniques, do not play any part in the precipitation of thrombi in the veins of the lower extremities.

In 69 cases which came to autopsy, we were able to cross check the repeated premortem blood levels of total fibrinogen, fibrinogen B, antithrombin, fibrinolysin, α-tocopherol, and the platelet count against the results of vein dissection. We were not able to substantiate the value of any of these tests in the diagnosis of actual or impending venous thrombosis. Thus, because we were unable to establish any relationship, we concluded that abnormalities in blood coagulation, of the types studied, are not important factors in the etiology of thrombosis.

We were impressed with the fact that 17 of the 21 incipient thrombi studied arose in valve, where stagnation of blood should be judged by the degree of organization in the thrombus, was at or near the apex of the valve, where stagnation of blood should be most extreme. In our over-all series the percentage of thrombi, both large and small, in the valve pockets was not nearly so high, but still was sufficient to substantiate our beliefs. We believe that the best prophylaxis against venous thrombosis and possible subsequent pulmonary embolism is the maintenance of an efficient circulation in the deep veins of the lower extremities. This might well be practiced (by posture) not only in the postoperative period but during the course of protracted operations.

Summary

Our observations on different facets of the problem of venous thrombosis are reviewed.

The common site of origin of venous thrombi was in the thigh and pelvic veins rather than in the calf veins.

Surgical ligation of the superficial femoral vein in pulmonary embolism, either prophylactically or therapeutically, does not appear to be basically sound.

Separation of thrombophlebitis and phlebothrombosis because of a supposed difference of embolic potential is not warranted.

Venous stasis in the veins of the pelvis and lower extremities rather than changes in the underlying vein wall or abnormalities in the blood coagulability is the important factor in the initiation of venous thrombosis.

The best prophylaxis against venous thrombosis is the maintenance of an efficient circulation in the deep veins of the lower extremities.

DISCUSSION

DR. F. BURNS PLEWES, Toronto, Canada: This paper by Drs. McLachlin and Paterson seems to be an extremely important one. It is important because it contributes to our understanding of what is often a catastrophe.

Statistics regarding pulmonary embolism probably underestimate its frequency because such surveys cover large public hospitals, and observers agree that the incidence of embolism is higher in private patients with special nurses, who are waited on hand and foot. Early rising is probably one reason that the frequency of thromboembolism has decreased since the late thirties, but it is still much commoner than it was before the use of the Gatch frame bed.

There is no way to predict pulmonary embolism, as Dr. McLachlin has shown, for there is no test for thrombophilia, and there is no practical and useful treatment for pulmonary embolism. Therefore, we are dependent on prophylaxis or the prevention of its recurrence if the patient has a small nonfatal episode. The latter is achieved by anticoagulants.

Much can be accomplished in the prevention of thigh and leg vein thrombosis by preventing venous stasis. The maintenance of an adequate flow by toe and leg exercises, deep breathing, and especially by keeping the bed flat or even elevating the foot of the bed seems of even greater value after the careful and exhaustive investigation described in the valuable paper to which we have just listened.

DR. HARRY H. MCCARTHY, Omaha: I have been interested in this subject for many years. A preliminary report was published in the *American Journal of Surgery*, in 1948, describing a method of prevention based on the pathologic physiology related to pressure ischemia of the legs and stasis of venous blood. Since then we are continuing some studies on the importance of the fatal and nonfatal pulmonary embolus with relation to thrombophlebitis and phlebothrombosis.

I should like to emphasize the importance of stagnation due to lack of muscular tone and, in addition to that, ischemia of the calf of the leg. The importance of this is somewhat difficult to prove experimentally, although we do have some important negative results in our experimental work.

Clinically, we have some very important positive observations which point to the importance of stagnation, and ischemia of the calf of the leg, resulting in destruction of the small venules and then propagation of the thrombus and finally the fragmentation of the thrombus, which starts its mission of death.

If a large series of cases are analyzed, such as those of Barker, Hines, and Allen, representing 175,000 surgical cases, one can deduct the following information, although these statistics were prepared for another reason:

The patient who has a bilateral hernia repaired shows a 100% greater chance of fatal thrombus than the patient who has a unilateral hernia repaired.

The patient who has an appendectomy for acute appendicitis, especially with peritonitis, has a 100% greater chance of a fatal embolus than the one who has an appendectomy for a chronic or interval appendicitis. A patient weighing more than 200 lb. (91 kg.) has a 100% greater chance of having an embolus.

The patient who has a long procedure, such as a radical mastectomy, gastrectomy, etc., has a much greater chance of experiencing an embolus than one who has a short operation. General anesthesia allows greater emboli than local procedures. The lateral recumbent position is more dangerous than the recumbent position. The common denominator in all of these conditions is pressure ischemia and stasis due to lack of muscle tone in the calf of the leg.

Time does not permit further discussion; however, our clinical and laboratory material certainly emphasize the importance of the paper given today by Drs. McLachlin and Paterson.

DR. JOHN J. CRANLEY, Cincinnati: There are two points that puzzle me very much, however, and I hope that Dr. McLachlin will have time to clear them up for me.

The first is how to explain away the clinical evidence that many, if not most, cases of thrombophlebitis begin in the calf muscles, where, as a matter of fact, there are many venous valves.

Second, some years ago Drs. McLachlin and Paterson reported their observations that a significant per cent of emboli arose from thrombosis in the pelvic veins and concluded therefore that superficial femoral vein ligation did not appear to be basically sound either as a prophylactic or therapeutic measure against pulmonary embolism. If many thromboses begin in the valve pockets which are numerous in the thigh and leg but absent in the pelvic veins, it is difficult to explain their findings that many emboli arise from a point above the superficial femoral vein. I think we must explain this before we condemn superficial femoral vein ligation in thromboembolic disease.

DR. JOHN MCLACHLIN, London, Ont., Canada: I believe that part of the confusion in this problem is caused by trying to assess indefinite clinical evidence, unless it is confirmed by autopsy findings.

We have been impressed with the number of thrombi which occur in the valve pockets in the region of the entrance of the superficial femoral veins into the common femoral vein. I am certain that some thrombi arise in the veins of the lower leg, but in our experience covering 34 cases, 19 of which produced pulmonary embolism, none of them was of the long type that is classically referred to in the pathological books.

We were forced to believe that a large number of these thrombi do arise in the thigh and the pelvic veins rather than in the calf veins. In our incipient thrombi we were impressed by the large number of them arising in valve pockets. However, when all of these thrombotic masses were considered, not nearly as high a percentage arose in valve pockets. Despite this, we felt that the over-all origin in valve pockets was sufficient to be of importance.

Any movements of the legs which encourage the maintenance of the deep venous drainage from the lower extremities should aid in the prevention of venous thrombosis and subsequent pulmonary embolism.

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Primary Tenorrhaphies and Tendon Grafting Procedures in Hand Injuries

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In recent years an increasing number of safety rules, safety devices, and regulations have been devised in industry to prevent injuries to the upper extremities. In addition, the prevention of accidents in children, about the household, and in farming communities has been given considerable publicity. However, in spite of the large number of precautionary measures that have been devised and advocated, these injuries still continue to be an important item in the daily practice of many surgeons. It is estimated that over 50% of the injuries in industry are injuries of the hand. Many of these are relatively minor, so that often only a few days to a week is lost from work. However, others are of such severity that a digit or even a hand may be lost, with resultant decrease in earning power for the wage earner, plus the necessity of many months and even years of rehabilitation. In children many accidents occur from broken glass, sharp objects, wringers, mangles, and so on. In the housewife severed tendons and nerves result from injuries from sharply lacerated wounds and broken objects. In farming communities injuries from saws, corn pickers, and so on often lead to severe and disabling injuries.

Many leading surgeons in the country are cognizant of the high incidence of hand injuries and have set up hand centers in various sections. This has been especially true since the War. The hand center at the City of Detroit Receiving Hospital was organized in 1937, and, except for the War years, has been in continuous existence. This clinic meets twice a week, and all problems concerning the hand are dealt with. Along with injuries, tumors and infections are evaluated and treated, but the larger number of cases are, of course, fresh injuries. The many fundamental concepts concerning hand trauma as devised by Koch and Mason are followed.

In the treatment of injuries of the hand, a knowledge of the basic anatomy and physiology is extremely important.

In any type of injury to the hand, the determining factor should be noted. For example, one would not attempt to suture a lacerated tendon resulting from a human bite. In fact, this is one type of injury where even the skin should not be sutured. The type of injury often decides just what definitive work should be done. For example, in sharply lacerated wounds in the flexor tendon sheath primary tenorrhaphy can be successfully carried out. However, in severe saw injuries, crushing wounds, and open fractures it probably would be better just to repair the skin, close the soft tissue defect, and then at a later date perform the definitive surgery.

In addition, besides the etiological factor, the time from the injury is extremely important. Flexor tendons in the tendon sheath should not be repaired after a few hours. Extensor tendons, however, can be repaired 6 to 12 hours after the injury occurs. Whether the use of antibiotics can prolong the time during which primary care can be carried out is rather difficult to ascer-

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tain. Antibiotics, however, are not a substitute for good surgery. After the etiological agent is determined and the extent of injury is ascertained, the patient is prepared for the operating room. Tetanus antitoxin or toxoid is usually given routinely; however, penicillin and other antibiotics may or may not be used. If x-rays are indicated, the patient is taken to the x-ray room, where these are obtained. A complete history of the patient's past life is obtained, a good physical examination is done, and a complete blood cell count and urinalysis are performed. Adequate operating room facilities are essential. Favorable surroundings and an interested house staff are absolutely necessary to obtain good results.[1]

If at all possible, the anesthesia should be general. Brachial block in skillful hands is useful.

After adequate anesthesia is obtained, the hand is shaved, the finger nails are cleaned, and then the entire hand and forearm is thoroughly washed with soap and water for 10 minutes. Saline may be used for irrigation. A blood pressure cuff is placed on the upper arm and is used as a pneumatic tourniquet to control bleeding. Sheet wadding is placed on the arm, and the blood pressure cuff is placed over this. The two rubber tubes of the cuff are placed toward the head of the patient. The cuff is maintained in place by means of wide roller gauze. After the arm is elevated for a minute, the cuff is rapidly inflated to 250 to 300 mm. of mercury.[2] The blood pressure cuff is released at the end of an hour and a half. If the procedure takes longer than that, it is reinflated.

Fine instruments are used for any hand procedure; skin hooks are used for retraction; mosquito forceps, fine Halsted forceps, and small Senn retractors are employed. Minimal debridement, with atraumatic technique, is employed.[3] Tissues are handled gently. Beating them with a gauze sponge by a strong, healthy, and eager young assistant should be discouraged with a strong firm reprimand. Care is taken to preserve all of the tissues possible. In severe crushing injuries where there has been loss of skin, sliding pedicle flaps, rotation flaps, or free split-thickness skin grafts should be applied. The wound is irrigated thoroughly with saline from time to time throughout the operation. In regard to incisions in the hand, midlateral incisions are made in the finger, while in the palm the flexion creases are followed.

Once the operator has obtained adequate exposure, and has identified the injured tendons and nerves, definitive surgery should be carried out. Nerves should be repaired even in wounds where it is deemed advisable not to repair the tendons. The digital nerves, although very small, are easy to repair; they can be accurately approximated with two small sutures, and sensation can be returned to an anesthetic finger. Fine 000000 or 0000000 nonabsorbable surgical (silk) sutures are used for nerve repair. In the larger nerves of the wrist, as many as 8 to 10 sutures can be placed about the median or ulnar nerve. In tendon repair, fine suture material such as No. 50 or 60 cotton or 000000 untreated white silk may be used. In the primary repair of flexor tendons in the wrist and palm, uniformly good results are obtained. This is also true of extensor tendons, where the results are usually excellent. Occasionally there is some slight limitation of flexion following an extensor tendon repair, but this is usually not very severe.

The repair of flexor tendons in the tendon sheath continues to give only fair results. Actually, if the injury is more than a few hours old, if the wound has been probed and examined under unsterile conditions, if it is a severe crush or saw injury, or if the surgeon who is presented with the problem is not interested in this type of surgery, it is probably better just to close the skin and then do a tendon graft a few weeks later. However, I feel that in selected cases a definitely good result can be obtained with a primary tenorrhaphy. In a typical case of a lacerated flexor tendon in the

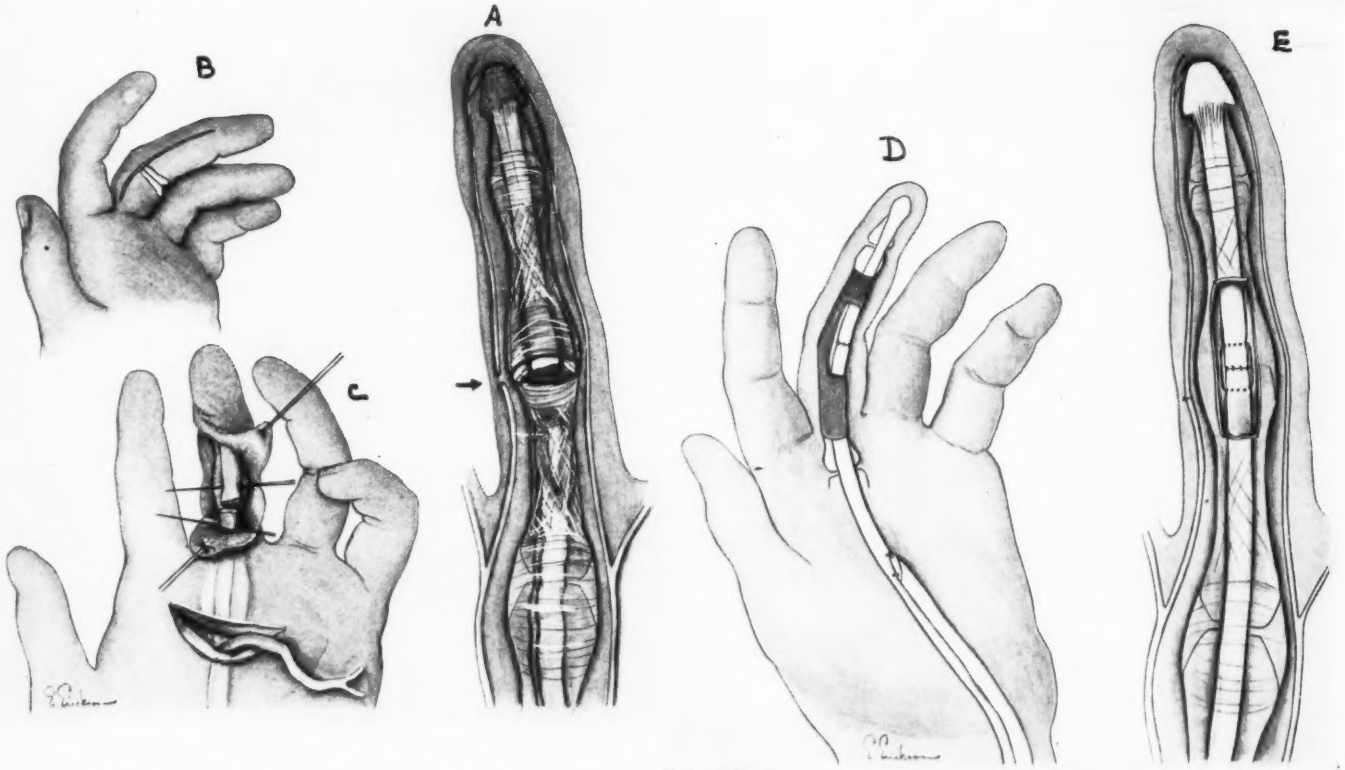

Fig. 1.—*A*, illustration of lacerated flexor tendon in the tendon sheath with severance of digital nerves and vessels. *B*, original laceration with midlateral incision on side of finger to obtain exposure. The vessels and nerves are retracted anteriorly. *C*, the flexor digitorum profundus is brought into the lacerated area. Note the needles placed at right angle to the tendon ends to prevent retraction. The accessory incision in the palm is extremely useful in locating the proximal portion of the flexor tendon. *D* and *E*, a window was then cut in the tendon sheath to prevent limitation of flexion. If this is not done, the suture will impinge on the fibrous tendon sheath. The proximal portion of the sublimis tendon is sutured to the proximal profundus. Note sutured digital nerve.

tendon sheath, usually the tendon retracts to the proximal portion of the finger and the tendon is located in the palm (Figure 1*A*). The tendon in the finger is exposed by means of a midlateral incision (Figure 1*B*). In the palm a transverse incision is made in the distal flexion crease. The proximal portions of the tendons are identified, the sublimis is allowed to remain in the palm, and the profundus is brought back in the flexor tendon sheath to the site of the lacerated wound. The flexor tendon sheath is opened, and the sublimis tendon is always removed. Precautions must be undertaken not to cut the insertion of the sublimis too long or it will attach to the flexor digitorum profundus, causing a contracture of the finger. On the other hand, it must not be cut too short or the proximal interphalangeal joint will hyperextend. This latter is often very troublesome and can be corrected only by attaching a tendon graft or distal portion of the sublimis tendon across the joint to the proximal phalanx in 10 degrees of flexion.[4] The tenorrhaphy is done on the profundus tendon. I have found, by using a small needle at right angles to the flexor tendon when it is brought to the wound, that excellent relaxation of the tendon ends can be obtained, and then they can be carefully approximated. A needle can also be placed through the distal end of the tendon (Fig. 1*C*). Sutures can be placed at right angles, although I have found good results with just simple through-and-through sutures carefully uniting the tendon ends. At the conclusion of the suturing, the tendon ends are carefully rolled together between the fingers and the tendon sheath is left open for gliding purposes[5] (Fig. 1*D* and *E*).

Fig. 2.—Severe laceration of the right hand in a 34-year-old television repair man who accidentally dropped a television casing on his hand. The patient suffered a lacerated flexor digitorum profundus and sublimis of the index, middle, and ring fingers and lacerated flexor digitorum profundus and a partially lacerated flexor digitorum sublimis of the little finger. In addition, the digital nerve on the ulnar side of the finger was cut in the index, ring, and little fingers. Primary repair was carried out on the flexor digitorum profundus in each of the fingers. The flexor digitorum sublimis was removed in the index, middle, and ring fingers. Primary neurorrhaphy was carried out on the lacerated digital nerves. Healing occurred uneventfully, and one year after the original injury the patient was able to make a good fist and bring his fingers well into the palm.

This seems to be the one single factor that does aid in getting good results in primary tendon repair in the finger. If the tendon sheath and tendon pulley are unroofed and allowed to remain open, a nice gliding space is provided and good results can be obtained. One should not hesitate to open the entire sheath or pulley if necessary. If bowstringing does occur, a pulley can be reapplied later (Fig. 2).

Occasionally only the flexor digitorum profundus is severed and the sublimis is intact. The question then arises as to what should be done. Motion of the finger is fair, but the distal phalanx is weak. I do a primary repair if conditions are favorable. If the laceration is near the insertion, a tendon advancement can be done.[6]

In the palm a primary tenorrhaphy can also be successfully carried out (Fig. 3*A*, *B*, *C*, and *D*). Here I often suture both the flexor digitorum sublimis and flexor digitorum profundus. A portion of lumbrical muscle is placed between the two tendons so that the suture lines do not become attached.

A primary tenorrhaphy is also feasible on the flexor pollicis longus, and the principles outlined for the repair in the flexor tendon sheath of the fingers are employed for this tendon.

In the wrist, in spite of the multiplicity of structures, primary repair is feasible. In this area we leave the volar carpal ligament open so as to provide a better gliding surface. Adequate exposure is obtained by enlarging the incision on either the ulnar or the radial aspect. However, one must be careful not to raise a large flap, because occasionally necrosis with delayed healing will occur at the edge.

In repair of the extensor digitorum communis tendons, good results are usually obtained in primary tenorrhaphies. Here the right-angle stitch, described by Mason, Koch, and Allen, works exceptionally well.

The extensor pollicis longus lends itself well to a primary tenorrhaphy. Occasionally, some difficulty is encountered in finding the proximal end; however, by making an adequate incision on the dorsal aspect of the wrist, the proximal end can be readily found and then threaded back to the lacerated site.

In my opinion, tendon-grafting procedures should not be done in acute injuries of the hand. This is especially true of tendons in the flexor tendon sheath.

Secondary Tendon Procedures

At times primary tendon repair is not feasible. For example, if a wound in the flexor tendon sheath is more than a few hours old, if it is a crushing or buzz saw injury, if open fractures have been encountered, or if the operator is inexperienced, secondary procedures should be considered. In addition, occasionally the original injury is overlooked, and then it may be necessary to do a secondary repair. Also, there is that occasional incident when a primary tenorrhaphy does not attain the functional result expected. Here, too, the use of a tendon graft or a secondary tenorrhaphy is indicated.

The optimum time, of course, for a tendon graft or secondary tenorrhaphy is within a month to six weeks after the original injury. Secondary repair may be done up to two months after the injury, but after this time it is often necessary to do a tendon graft. Two years has been said to be the limit of tendon-grafting procedures; however, we have done cases as long as 7, 13, and 18 years after the original injury. If infection has ensued following the primary closure, then one must wait until a secondary procedure can be carried out. One should plan ahead. The joints must be in good condition and the skin soft and pliable. It may be necessary to apply a pedicle graft to provide a nice gliding surface. Sensation should be intact, but, if necessary, a secondary neurorrhaphy can be carried out at the time of the secondary tendon repair.

In the operating room, the principles similar to those in a primary tenorrhaphy are followed. Tendon leaders and tendon strippers are used to facilitate the procedure.

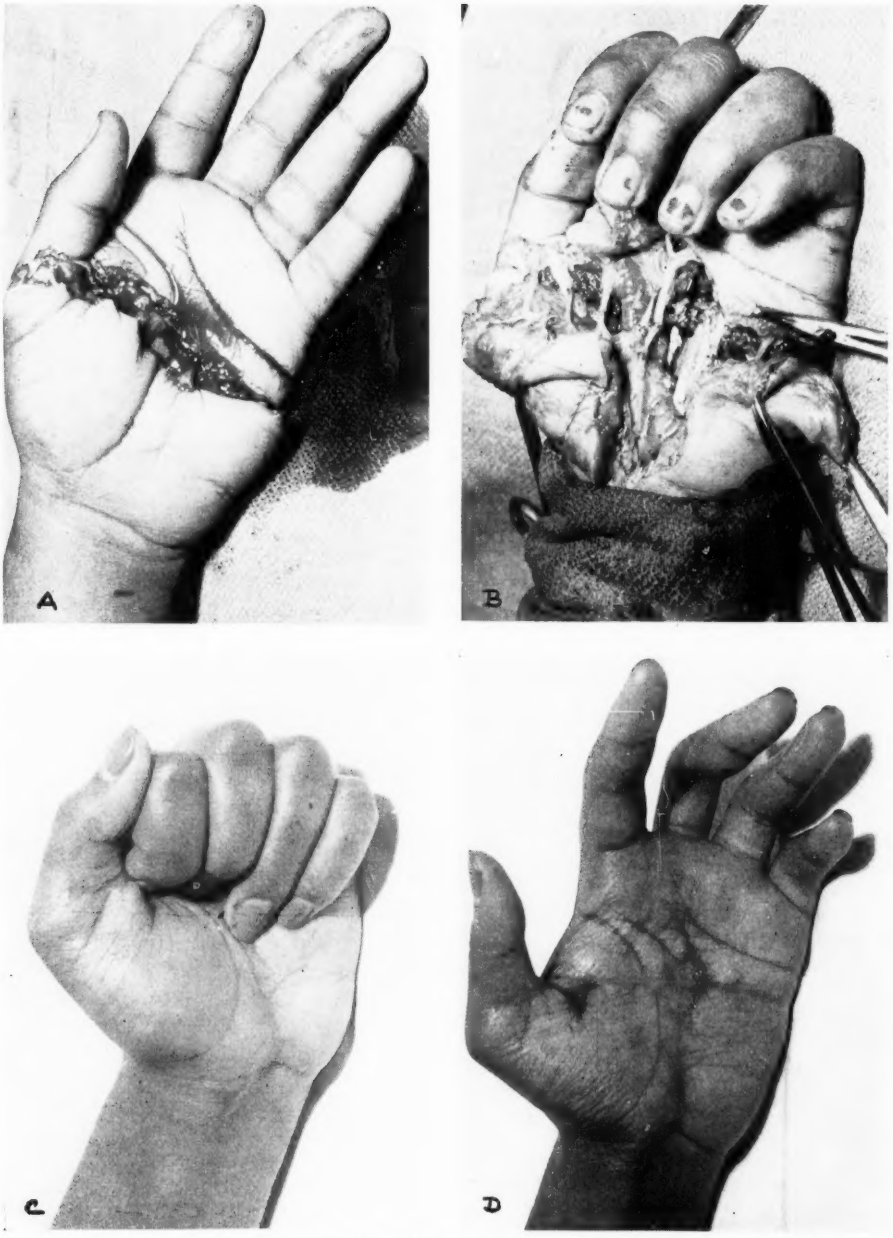

Fig. 3.—*A*, a 26-year-old housewife suffered a severe laceration of all the structures of the palm of her left hand except the recurrent median nerve *B*, primary tenorrhaphy was carried out on the flexor digitorum profundi and flexor digitorum sublimi. The lacerated branches of the digital nerves of the median and ulnar nerve and the deep motor branch of the ulnar nerve were also repaired. *C* and *D*, subsequently the patient regained good flexion and good extension of her hand. There is still evidence of ulnar nerve paralysis, and this is probably permanent. Sensation, however, has returned to the fingers.

In regard to sources for grafts, the extensor digitorum longus tendons of the second, third, and fourth toes work very well. In addition, one may take the palmaris longus or the flexor digitorum sublimis tendon. In taking tendons from the foot, a long semicurved incision is made and the tendon and the surrounding peritenon are removed.

With the use of general anesthesia, the incisions are made in the midlateral position of the finger and accessory incisions are made in the palm (Fig. 4*A*). If at all possible, one should save the tendon sheaths. However, if they are scarred or destroyed they should be removed. Later, if necessary, a pulley can be applied. In recent years, Boyes has used a nonabsorbable suture to unite the deep digital fascia at the midjoint level, which gives a good pulley effect.[7] I have done this with excellent results. At the insertion of the flexor digitorum profundus in the distal phalanx the periosteum is roughened, the tendon is opened into a V-shape, and the tendon graft is then sutured to the tendon insertion itself. Occasionally,

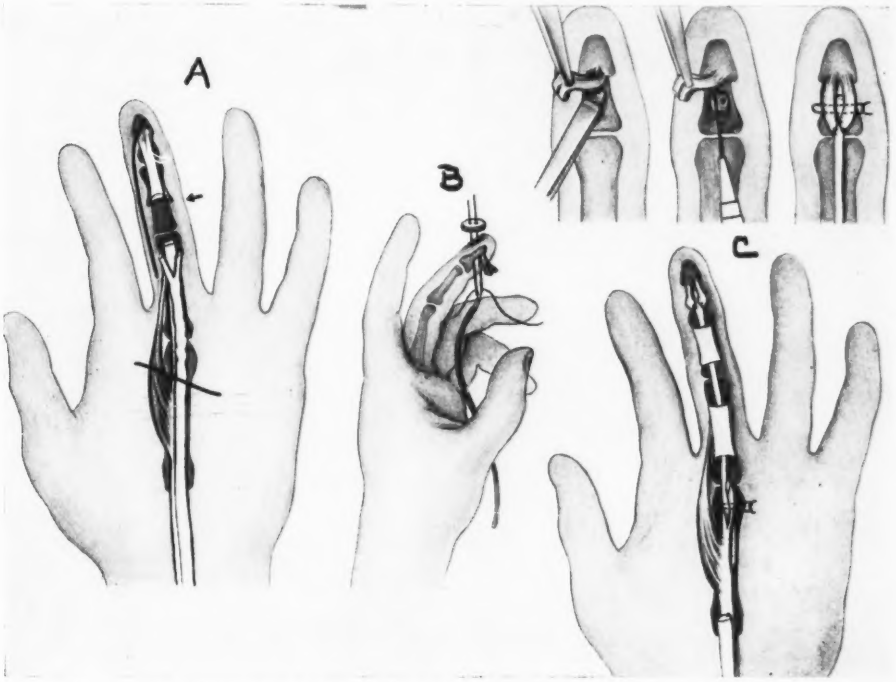

Fig. 4.—*A*, technique in tendon-grafting procedures. The incision is made on a midlateral aspect of the finger, and the accessory incision is made transversely in the midportion of the palm. *B*, the procedure employed when a ruptured tendon is encountered or when the insertion of the profundus is too small to carry out a good approximation. A small chip of bone is raised in the distal phalanx. By means of a small hand drill or electric drill two small holes are placed underneath the elevated bone through the distal phalanx, to come out through the nail. The small tendon graft is united to the insertion of the profundus by bringing it to the roughened periosteum or under the chip of bone raised in the distal phalanx. The ends are then carefully united to the portion of profundus that remains. In cases of ruptured tendon where a small stump of profundus is left a wire is placed transversely through the end of the tendon graft. The wire is then brought out through separate drill holes to the nail and tied over a button. This tendon is then held in tight approximation to the exposed periosteum or the area where the bone chip has been elevated. This wire is removed in six weeks. *C*, the proximal portion of the tendon graft is united to the profundus by making a small split in the profundus and then uniting the graft and proximal portions of the profundus with small interrupted sutures.

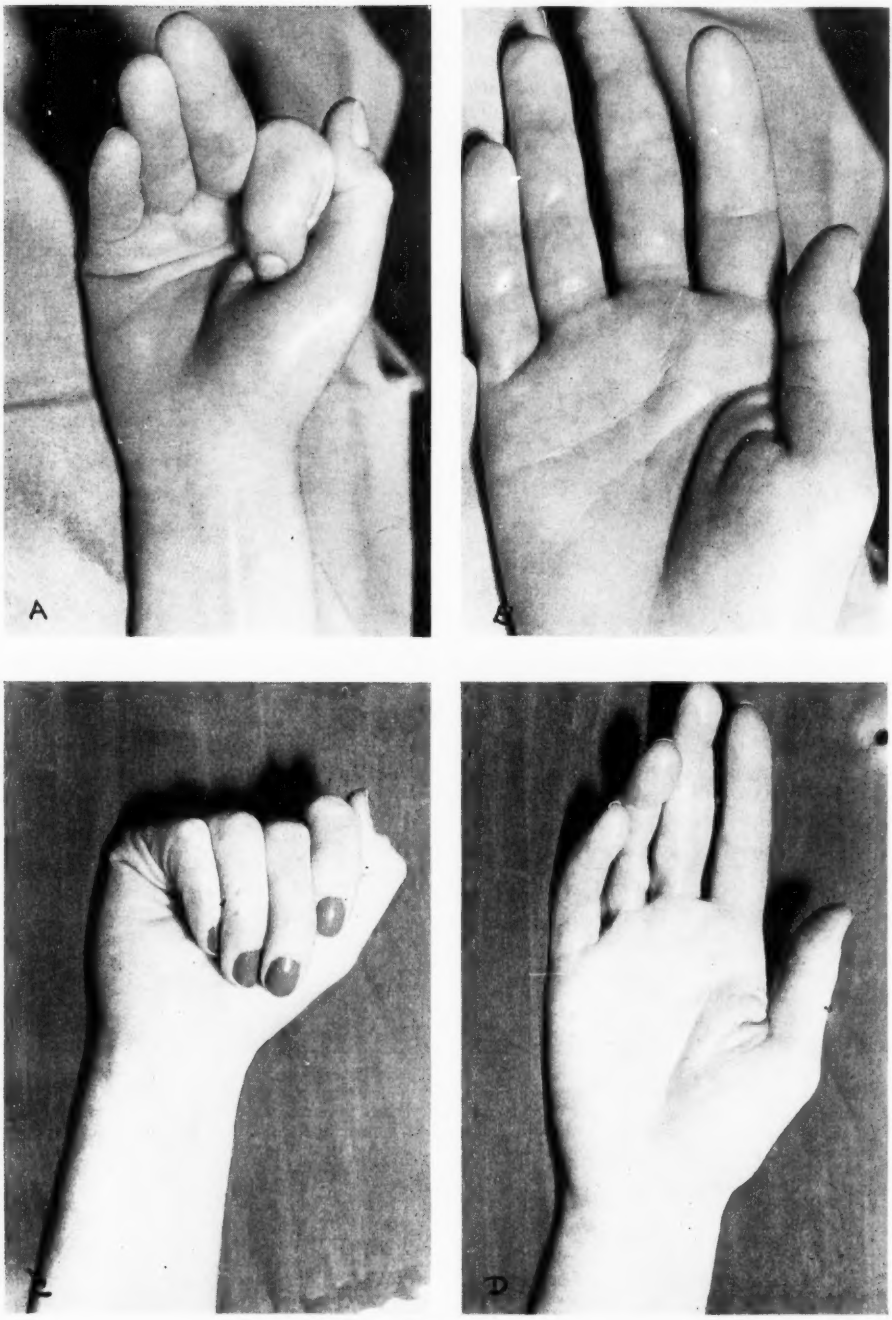

Figure 5

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the tendon may have ruptured at its insertion, and, in that case, I often chip a piece of bone out and place two drill holes through the phalanx and through the nail and hold the tendon to the bone with wire (Fig. 4*B*). This wire is removed six weeks postoperatively.

An important point in doing these secondary tendon repairs is that the sublimis and profundus tendons in the palm should be carefully freed in the proximal portion, especially in older persons where a certain amount of thickening in the palmar fascia has occurred. The profundus is completely freed and then brought into the wound. It is prevented from retracting by placing a needle at right angles to it. In suturing the tendon graft to the proximal profundus, I employ the method that the late Dr. Harvey Allen described to this organization at a meeting in 1951.[8] A slit is cut in the profundus; the graft is placed through it and sutured to it (Fig. 4*C*). The tension is a little difficult to determine. It has been stated previously that these tendons have a tendency to contract and should be placed a little long. However, I have found that the best result is obtained if wrist and hand is held in a neutral position and if the tendon is placed on a little more tension than normal (Figs. 5 and 6). If the nerves are lacerated, 000000 silk is used, and fine nylon sutures are used for the skin.

I have found that, in the finger, tendon-grafting procedures work much better than secondary tenorrhaphies. Perhaps if the secondary tenorrhaphies were seen within a few weeks the results would be good; however, those that I see are usually many months old, and often when a secondary tenorrhaphy has been done in the tendon sheath I have had a cause to regret it. Tendon advancement may be done if the laceration is near the insertion of the profundus. One can advance the proximal portion of the tendon directly to the insertion of the flexor digitorum profundus into the distal phalanx.

I have found that, even with the flexor digitorum sublimis intact and with the flexor digitorum profundus cut in the finger, tendon-grafting procedures are of aid. A small tendon graft is threaded between the slips of the sublimis and united to the profundus in the palm, and the steps outlined above are followed. Although it is rare to obtain a complete range of motion after this procedure, the patient does have strength in the tips of the fingers and is able to use them very well.

In the palm it is usually necessary to do tendon-grafting procedures.

In the wrist, either tendon-grafting procedures or secondary tenorrhaphies work well.

Lacerated or ruptured extensor tendons at the distal interphalangeal joint give a good deal of trouble in reconstructive surgery of the hand.

Ruptured tendons may be treated by splinting with good results, but some men advocate immediate surgery.[9]

In secondary repair the scar tissue can be excised and the ends approximated. The scarred tendon can be overlapped, or a tendon-grafting procedure can be carried out. This consists of drilling a small hole directly through the shaft of the midportion of the distal phalanx and threading a small tendon graft (a portion of the palmaris longus) and then uniting it to the proximal portion of the tendon over the middle pha-

Fig. 5.—*A*, unsuccessful primary tendon repair in the flexor tendon sheath of the middle, ring, and little fingers had been carried out on this 31-year-old waitress elsewhere. Tendon-grafting procedures employing the long extensors of the toe were carried out seven weeks after the original injury. Two months later a tendolysis was carried out to the graft of the middle, ring, and little fingers and a tendon-shortening procedure was done on the middle finger. The patient subsequently developed hyperextension in the proximal interphalangeal joint of the middle finger. This was corrected by suturing the joint capsule on the anterior aspect and also placing a small tendon graft across the joint to maintain slight flexion. Note lack of flexion preoperatively. *B*, the amount of extension preoperatively. *C*, flexion possible 18 months after tendon-grafting procedures were carried out. *D*, extension possible. The patient was able to return to work as a waitress, and she is using her hand without being handicapped in any manner whatsoever.

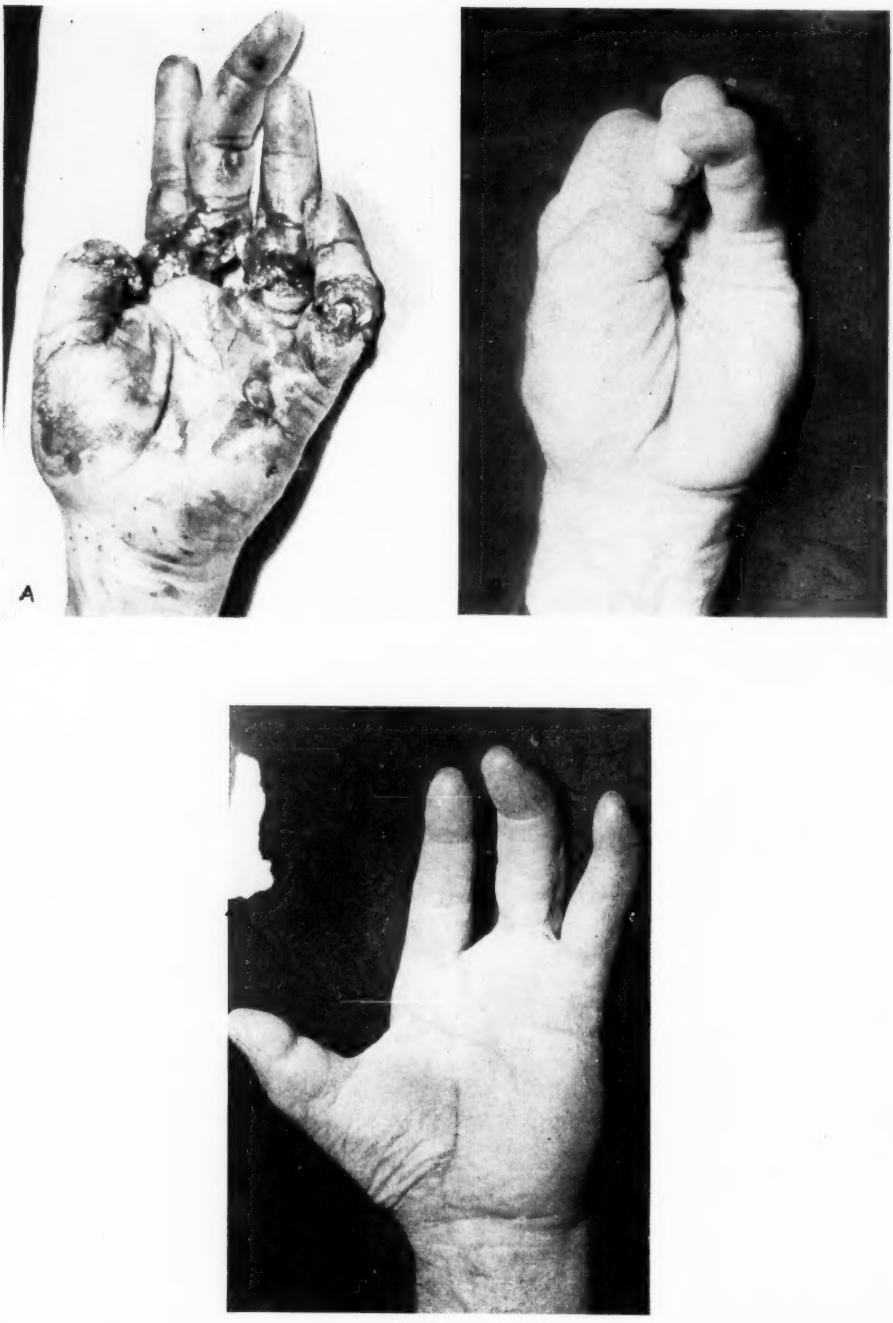

Figure 6
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lanx.[10] Reduction is maintained by splinting, or by a Kirschner wire through the distal joint, maintaining the distal joint hyperextended for four to six weeks.

For lacerations over the dorsal aspect of the proximal interphalangeal joint, Fowler's method may be used.[11] This consists of drilling a hole at right angles to the shaft of the middle phalanx. A narrow tendon graft is placed through this and crisscrossed subcutaneously over the joint to be united to the interossei on the other side. Rank and Wakefield suggest that the interossei be detached on each side and crossed over to be united to the opposite interossei.

In regard to the extensor pollicis longus, I rarely am able to unite the ends in a secondary procedure, but resort to tendon grafting, employing the palmaris longus or the extensor tendons of the toes, or, on several occasions, I have transplanted the extensor indicis proprius and used that as the proximal motor power. This is especially true in tendons ruptured in Colles fractures or in tendons that have been injured previously (Fig. 7).

In the primary tenorrhaphies the wounds are closed without any drains whatsoever. In the elective tenorrhaphies, secondary tenorrhaphies, and tendon grafts, several small rubber drains are inserted between the skin edges after the wound has been closed. A large compression type of dressing is utilized. Gauze dressings are placed between each finger to prevent maceration. The metacarpophalangeal joints are carefully padded, as are the prominent bony structures of the wrist. Large abdominal pads are then placed over the gauze squares. These are maintained in place with roller gauze, and then the appropriate splint is applied. This can be either metal or plaster of Paris. For flexor tendons, the wrist is flexed 45 degrees and the digits are flexed 15 degrees at each joint. For extensor tendons, the wrist is dorsiflexed 15 degrees, while the fingers are slightly extended, but not to 180 degrees. An elastic bandage is then placed over this dressing. We have found the use of a hand pack in the operating room of great aid in doing dressings. This pack includes the necessary requirements for a dressing, such as gauze squares, abdominal pads, roller gauze, elastic bandages, and metal splints. After the application of this dressing, the patient is sent to the recovery room to recover from his anesthetic. When he is returned to his bed, the hand is elevated on several pillows. The fingers are watched for swelling and cyanosis. When the patient is ambulatory, he has his arm in a sling. The patient is encouraged to move his shoulder several times a day, since we have noted several cases of bicipital tendinitis and subdeltoid bursitis following operations on the hand. The patient is ambulatory as soon as he desires; even when the extensor digitorum longus has been taken from the foot and used as a graft he is not kept in bed for any longer period of time. The hospital stay depends a good deal on the patient's individual desire. This can vary from three to seven days. In primary tenorrhaphies antibiotics are used rather frequently, but not routinely. In the elective cases antibiotics are used only rarely. I have not used cortisone in any of my tenorrhaphies. The day after surgery the elastic bandages are loosened, and if the gauze bandages are too tight these

Fig. 6.—*A*, severe injury on the left hand of a 62-year-old "do it yourself" fan, which occurred when he was injured on a skill saw at home. Severe injury occurred to all of the flexor tendons, digital nerves, and blood vessels to the thumb and fingers of the hand. The middle finger was just hanging by skin, and this was removed. At the initial procedure an anastomosis of the blood vessels was carried out. The fractures were reduced, and the hand was dressed on a universal metal splint. Six months after the injury a secondary neurorrhaphy was done on the digital nerves, and tendon grafts employing the extensor tendons of the toes were placed in the thumb, index, ring, and little fingers. The patient subsequently developed a fairly well-functioning hand and was able to return to work. He retired at 65 and then built a cabin in the woods. *B*, Flexion possible following extensive reconstructive surgery. *C*, Extension is good. There is still a good deal of ankylosis of the proximal interphalangeal joint of the little finger, but the patient was able to grasp objects with his thumb, index, and ring fingers. Sensation has returned to the fingers.

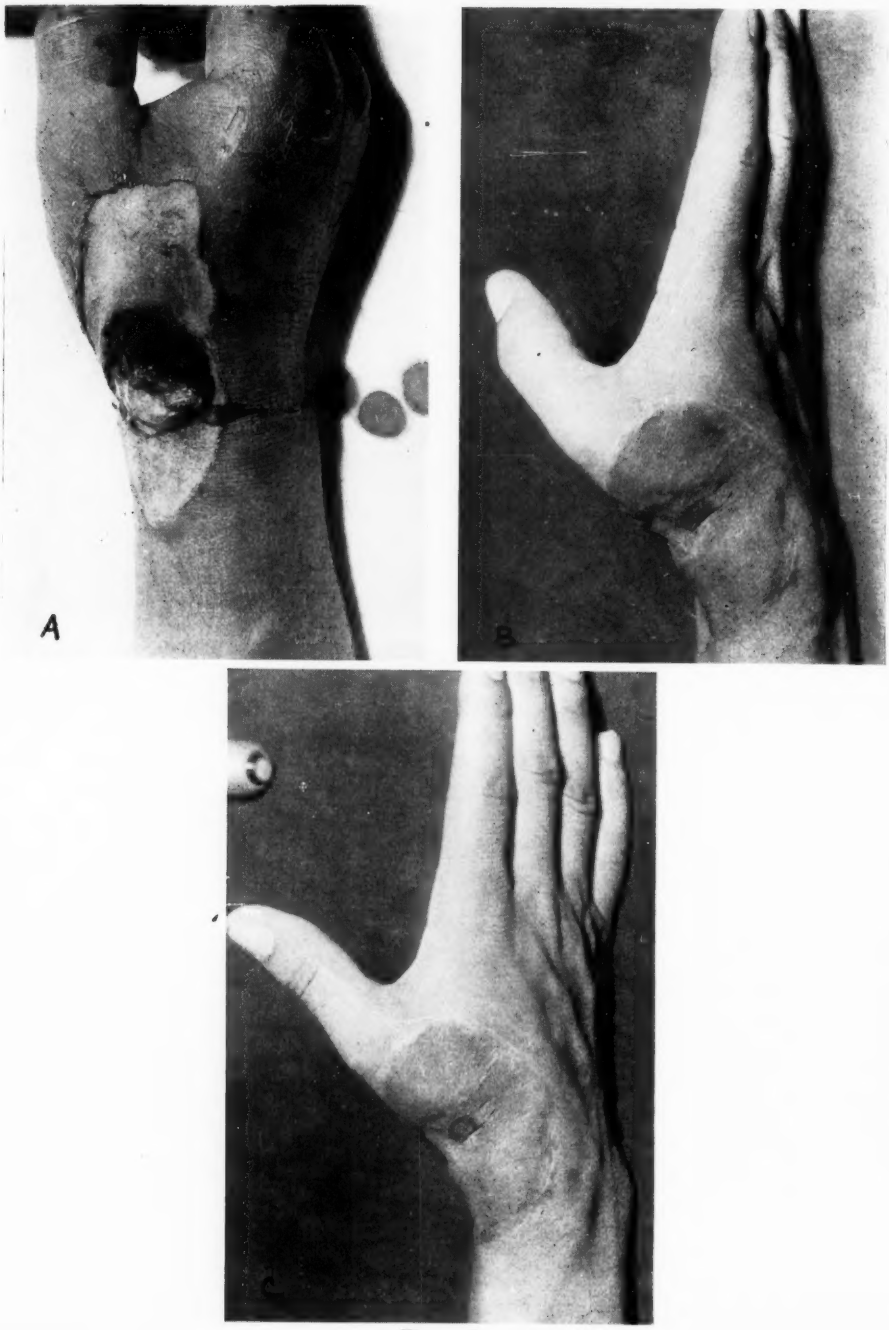

Figure 7
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are loosened. The dressing is then reapplied. In secondary tenorrhaphies the small drains are removed at the end of four or five days. The hand is then redressed and left undisturbed for another week. At the end of that time, the sutures can be removed, and, if necessary, the hand can be carefully washed in soap and water, maintaining the desired position, however, while this is carried out.

In regard to the period of immobilization, the flexor tendons are immobilized for three weeks, with complete immobility, and then for another week a splint is worn on the dorsal aspect of the wrist, maintaining the fingers and hand in a neutral position. At the end of four weeks warm soapy hand baths are carried out several times a day, and gradually increased motion is encouraged. Rubber sponges, rubber balls, and wooden blocks all aid in obtaining good function.

In cases involving extensor tendons the fingers and thumb are maintained in extension for four weeks and then splinted in a neutral position for 7 to 10 days. At night the splint is worn for two or three more weeks. In the treatment of these injuries in children, the first change of dressing is usually done under general anesthesia. By this method, sutures can be taken out and the appropriate splint reapplied without disrupting the continuity of the tendons or nerves. The second dressing is then left on until the repaired structures are well healed. At times one may even keep the initial dressing on for three to four weeks before it is removed. We have found that in the case of extensor tendons, once motion is resumed, occasionally there is a tendency for a slight lag to occur. This is true following either primary tenorrhaphies or tendon grafts; however, gradually within a period of a few months, a complete range of motion is attained. In flexor tendons, motion, too, may be rather slow early, but eventually good function does ensue. All of us have seen cases that appear to have a discouraging results after a few months, but in a year or two they have an excellently functioning hand and a good useful one. Formal physiotherapy is utilized for the patients who appear to be making slow progress or those who do not appear to be very cooperative. This is especially true in the industrial accidents, where compensation problems bring many intangibles into the picture of rehabilitation. In children excellent results are often obtained without any formal course of follow-up care.

Conclusions

The results are presented for 340 cases seen during the previous five years in Tables 1 to 5.

In Table 1 are listed the operative procedures that were performed. The relatively large number of tendon grafts over secondary sutures of flexor tendons is due to the fact that if there was any doubt at all of the gliding surface of the scarred flexor tendon at the secondary procedures a tendon graft was done rather than a tendolysis. Injuries of the extensor tendon at the distal interphalangeal joint are listed separately, since the results are poor in this type of injury. This tendon has been listed by

TABLE 1.—*Operative Procedures*

	Cases, No.
Flexor tendon grafts	138
Primary tenorrhaphy of flexor tendons	69
Primary tenorrhaphy of extensor tendons	43
Repair of extensors at distal interphalangeal joint	31
Secondary suture of flexor tendons	29
Extensor tendon grafts	20
Secondary sutura of extensor tendons	16

Fig. 7.—*A*, severe grinding injury in a 26-year-old auto factory employee, with destruction of skin and loss of extensor pollicis longus. Primary treatment consisted of excision of the necrotic areas and the application of a split-thickness skin graft. Five months after the original injury some scar tissue was excised over the metacarpal carpal area. Nine months later a tendon graft employing the extensor tendon of the toe was done to the extensor pollicis longus. *B*, skin graft well healed. Note limitation of extension of distal phalanx of thumb. *C*, excellent function following tendon-grafting procedure.

others as being an unsolved problem, and I still find it to be so. My procedure at the present time is that outlined previously, that is, to do a secondary suture of the injured area by excising the scar or overlapping it, maintaining reduction by means of a small Kirschner wire placed only through the distal interphalangeal joint.

In Table 2 are listed the results of the tendon grafts of both the flexors and extensors. In my tendon grafts for the flexor

TABLE 2.—*Tendon Grafts*

	Cases, No.	Satisfactory Result
Flexor tendon grafts		
Wrist	4	4
Palm	8	8
Thumb	34	25
Fingers	98	73
Extensor tendon grafts		
Wrist	2	2
Thumb	10	10
Fingers	8	6

tendons, the extensor digitorum longus was used 109 times, the flexor digitorum sublimis, only 9 times, and the palmaris longus, 20 times. The palmaris longus tendon was usually used for tendon grafts to the thumb. The results for tendon grafts in the wrist and palm are, of course, usually good. In the thumb, strength and power are also noted, but the complete return of function itself is rare.

In the fingers there were 98 flexor tendon grafts, with 73 good results. The poor results were usually in fingers that needed tendon shortening or whose joints were very stiff. Actually, these cases probably should not have been selected for tendon grafting. Again, in these cases a complete normal return of function is extremely rare; however, good functional results are obtained in most of them. I found that the best results occurred where the extensor digitorum longus tendon was used. This tendon was removed with its surrounding peritenon, and it appeared to provide a nice gliding surface.

In the extensor tendon grafts, uniformly good results were obtained in the thumb and wrist.

In Table 3 are shown results of primary tenorrhaphy of flexor tendons in the digital

TABLE 3.—*Primary Tenorrhaphy*

	Cases, No.	Satisfactory Results
Flexors		
Fingers	45	39
Palm	16	15
Thumb	17	16
Wrist	28	28
Extensors		
Fingers	26	25
Thumb	14	11
Wrist	7	7

sheath; good results were obtained in 39 of 45 cases. In one case amputation was performed. In two cases subsequent tendon-grafting procedures had to be performed. One case, a severe saw injury, developed a rather nasty infection, which eventually cleared. This patient had fair function, but a large amount of atrophy distal to the laceration occurred.

In the palm uniformly good results were encountered in primary tendon procedures. In the thumb, after primary tenorrhaphies, good strength was noted in 16 of 17 cases. Again, the complete range of motion returned only in the younger age group, but good, functioning thumbs were obtained in practically all cases. Uniformly good results were obtained in the wrist.

In regard to primary tenorrhaphies for the extensor tendons, good results were usually obtained in the fingers. In the thumb in three instances weakness on extension was noted, especially in cases sutured about the metacarpophalangeal joint. Primary tenorrhaphies of lacerated extensor tendons in the wrist presented no problem.

In Table 4 it is shown that secondary sutures of the flexor tendons in the tendon sheath resulted in good results in 13 of 18

TABLE 4.—*Secondary Suture*

	Cases, No.	Satisfactory Results
Flexors		
Fingers	18	13
Palm	5	3
Wrist	10	9
Thumb	5	2
Extensors		
Fingers	13	10
Thumb	3	3

cases. In the palm and wrist fairly good results were noted. In the thumb secondary suture results were poor. Secondary suture of the extensor tendon could be carried out on the finger with good results, especially over the metacarpophalangeal joint.

In Table 5 we find that the results in ex-

TABLE 5.—*Results in Extensor Tendons at the Distal Interphalangeal Joint*

Cases, No.	Results		
	Good	Fair	Poor
31	12	10	9

tensor tendons injured at the distal interphalangeal joint are usually poor. Of 31 cases, good results were noted in only 12. Secondary suture and tendon grafting procedures were carried out in several cases. In tendon grafting procedures no remarkable results were encountered. This does continue to be the unsolved tendon problem, as mentioned previously.

Summary

A series of cases, 340, involving primary and secondary tendon procedures are presented. It is felt that in selected cases a primary tenorrhaphy can be performed with good functional results. In other cases, tendon grafting procedures, especially in flexor tendons, are the method of treatment. Extensor tendons lend themselves well, with good results, to a primary tenorrhaphy. The primary repair of lacerated flexor tendons in the palm and wrist also gives good results.

In tendon grafting procedures, I have found that the extensor digitorum longus of the second, third, and fourth toes works exceptionally well and gives exceptionally good results.

Infection plays an increasingly diminishing role in the treatment of these injuries of the hand. There were only 2 infections in 138 cases of flexor-tendon-grafting procedures. One of these followed the development of a hematoma in the finger. Subsequently a tendolysis was carried out, with an excellent return of function. The other occurred in the palm, following a flexor-tendon-grafting procedure, and it was not severe. In the primary tenorrhaphy group only one infection was encountered.

With increasing interest in surgery of the hand, with the development of improved technique, and with the establishment of hand centers throughout the country, the outlook for decreased loss of time from injuries of the hand and decreased periods of rehabilitation is excellent.

DISCUSSION

DR. CHARLES G. JOHNSTON, Detroit: I want to congratulate Dr. Posch on presenting a rather broad subject in a very concise and clear manner. Further, I want to thank Dr. Posch for the great contribution he has made in the Detroit area in the care of the injured hand.

This is a very important problem with us. A man with a crippled hand is not much of a workman, and I think all of us recognize, from what Dr. Posch has said, that it is most important to take care of these people promptly, because when it is possible to do a primary tenorraphy it is so much better than secondarily. On the other hand, when there is any problem in making a primary tendon suture, it is much better to close the wound and wait until one has a clean run at the tendon grafting later.

All too often—and we have experienced this and we still experience it to some degree—the residents and our staff people who are supervising these cases, especially at night, when a good

number of our patients with tendon injuries come in, don't feel that these are important. They feel it is a superficial thing, and usually it is pushed onto the Junior Resident, because there is usually some other case that has much more extensive surgery to be done. Yet these hand cases are much more important than many other cases that the average resident would rather have to do, or that the average staff man would feel is worth his while doing.

Dr. Posch, with us, has done a great job of emphasizing the importance of this problem and also has been very helpful in seeing that each and every resident gets a good concept of the importance and the techniques of the care of the injured hand.

The problem of the technique, of course, relates definitely to the type of injury, and all too often, since the laceration is so obvious, many persons do not take the time to carry out the physiological tests that Dr. Posch has indicated. It is rather important to know what you are going to do before you get in there, because unless you are sure about the anatomical structures, and sure about the injury that has been done from a functional standpoint, you are likely to overlook injuries because of the retraction of the tendons into the sheath.

I am sure all of us appreciate Dr. Posch's presentation this morning, and I for one am very happy that Dr. Posch has given us so much help in taking care of this problem. The injured hand is not nearly so difficult a problem with us as it was some years ago, because of Dr. Posch's persistent interest.

Also, there is one thing that I am sure Dr. Posch meant to say, which I think is exceedingly important: These people, after their tenorrhaphy, are not sent to a physical therapist and forgotten, with the idea that the physiotherapist will take care of the after-care and get the patient's hand function back. Dr. Posch in each of these instances has followed the case through until the person is back at work again, or until he knows that something else has to be done.

I think that is very, very important. These people need the type of physiotherapy the patient and the doctor can get for themselves, without shipping them off to a second party who will not follow through quite as well.

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An Experimental and Clinical Study of Vascular Spasm

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Over the past three to four decades, vascular spasm in the extremities has become a subject of increasing clinical, as well as some experimental, interest. The experimental work done has been in an effort to relate localized trauma of a major artery to subsequent spasm of the arterial tree. This experimental work was initiated at the suggestion of Dr. W. T. Mustard, following the occurrence of vascular spasm with well-marked Volkmann's ischemia in the lower extremity after traction in the treatment of fractures of the femur in childhood (Thomson and Mahoney, 1951).

It was felt that an effort should be made to show that arterial spasm can be initiated consistently following stretch of the vascular tree, either from its resting state or after previous shortening, and that localized trauma is not a necessary factor in the production of this spasm.

Experimental Observation

The experimental findings have been reported previously (Mustard and Simmons, 1953). In view of their relation to the clinical cases, they will again be described.

With the use of dogs, an experimental investigation was carried out with a radiographic method of study allowing simultaneous comparative arteriograms of both lower limbs. To do this a "tap" was placed in the arterial system by means of a polyethylene tube secured in the left renal artery after a preliminary nephrectomy on that side. With this method, arteriograms were taken initially to indicate the normal state and then at varying periods following stretch of the vascular tree from its resting or previously shortened state.

Stretch of the vascular system was obtained by lengthening the femur for approximately 5/8 in. and maintaining this length by a bone plate. Where previous-shortening was desired, the femur was allowed to shorten for 24 hours and then the fragments were plated in their normal position and alignment, with no distortion of the length of the femur.

Four experiments were carried out in which the vascular system was studied before and at varying periods after lengthening of one femur. When stretch of the vascular tree from its normal resting state was carried out in one lower extremity, there consistently developed marked arterial spasm of the affected limb with almost equally well-marked spasm in the uninjured extremity (Figs. 1 and 2). This spasm was diffuse and involved the collateral as well

Fig. 1.—Arteriogram before fracture.

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This work was done in the Department of Surgery at the University of Toronto and was aided by a Grant from the Banting Research Foundation.

Fig. 2.—Arteriogram 24 hours after 5/8 in. lengthening.

as main vessels. Early signs of ischemia, in the form of coldness, lack of pulsation, and edema were associated with the spasm initiated in these cases. The clinical evidence of ischemia and the radiographic evidence of spasm were both more marked in the lengthened side.

The animals were killed, and the muscles and vessels of the limbs were explored. The arteries and veins were in marked spasm, but there was no obstruction due to thrombosis or any localized pressure. The muscle bellies were firm, swollen, and pale and exuded a watery edema fluid.

Microscopic section taken below the femoral-tibial articulation at 72 hours (Fig. 3) showed marked protein-rich edema fluid in the muscle, subcutaneous tissue, and skin. The separation of muscle fibers by edema fluid is apparent. Dilated lymphatics are present in the connective tissue filled with fluid, and the interesting finding of rather marked vesiculation of the skin is noted. The gross and microscopic findings in these cases correspond well to the early changes of muscular and limb ischemia previously described (Mustard, 1946; Thomson and Mahoney, 1951).

In another group, of four animals, the limb was allowed to shorten for 24 hours and then the bone fragments were plated in

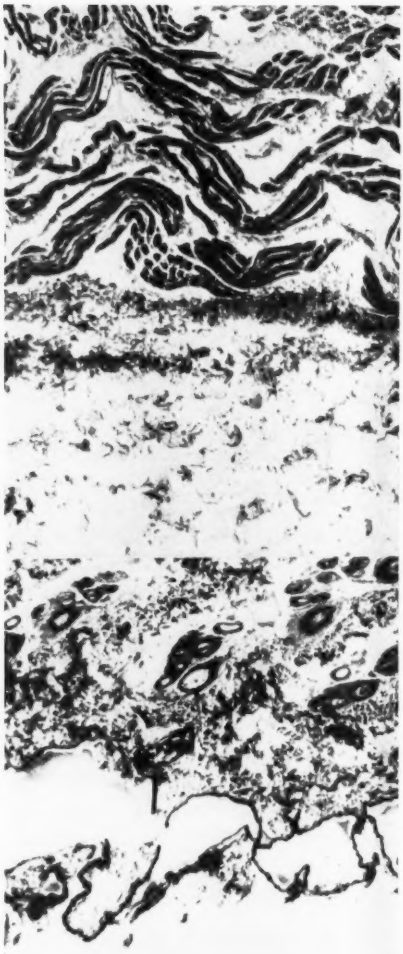

Fig. 3.—Section through muscle, subcutaneous tissue, and skin 72 hours after lengthening the leg; note the protein-rich edema of muscle and subcutaneous tissue and vesiculation of the skin. Hematoxylin and eosin; ×48.

their normal position and alignment. The normal position was determined by screw holes which were drilled before fracture. Arteriographic studies were made before fracture and approximately 24 hours after return to normal length. When the fractured femur was allowed to shorten for 24 hours and then brought out to normal length, the same changes of diffuse bilateral arterial spasm and associated clinical ische-

mia were produced. The radiographic evidence of spasm was even more marked in these cases, and the clinical findings were more extreme. Again, the spasm was of both main and collateral vessels, and the spasm and clinical findings were more marked in the fractured side (Figs. 4 and 5). In this case only a thread of dye is seen in the main artery of the uninjured limb 24 hours after return to normal length. There is none in the foreshortened limb.

To show that the operative procedure was not the factor which initiated the vascular spasm, three control experiments were carried out. In these the femur was completely fractured across at its midpoint; the fragments were not allowed to shorten, and they were plated in their normal position and alignment. Arteriographic examinations made before and approximately 24 hours after fracture and plating revealed no detectable evidence of arterial spasm (Figs. 6 and 7).

Clinical Observations

Over the past two years certain clinical cases have been observed in which it was

Fig. 4.—Arteriogram before fracture.

Fig. 5.—Arteriogram 22½ hours after return to normal length.

Fig. 6.—Control experiment, arteriogram before fracture and plating.

Fig. 7.—Arteriogram 22 hours after fracture and plating without allowing shortening.

felt that vascular spasm was induced by stretch of the vascular tree. Generally, this stretch was exerted on a portion of the vascular system which was in a shortened state as a result of existing deformity. The subsequent spasm produced severe states of ischemia.

CASE 1.—A 2½-year-old girl suffered multiple congenital anomalies, including congenital flexion deformities of 60 degrees at the left knee and 30 degrees at the left hip.

An extensive soft tissue release was carried out behind the left knee, and a fracture was made in the region of the epiphysial plate, allowing full correction. The limb was immobilized in fairly full extension in a spica.

By the third day the toes were cold and cyanosed and the patient was unable to move them. On the

Fig. 8.—Lateral view of lower limb days after attempt to straighten congenital flexion deformity of knee.

fifth postoperative day the cast was removed. The foot was pulseless, with all the gross signs of severe ischemia. Figure 8 is a lateral view of the limb eight days postoperatively, after four sympathetic blocks. Persistent swelling, blistering, and lividity are evident. This child was left with a fixed Volkmann contracture, with no movement below the knee.

The mechanism by which straightening of this child's limb would create traction in her vascular tree is indicated (Fig. 9). It is an

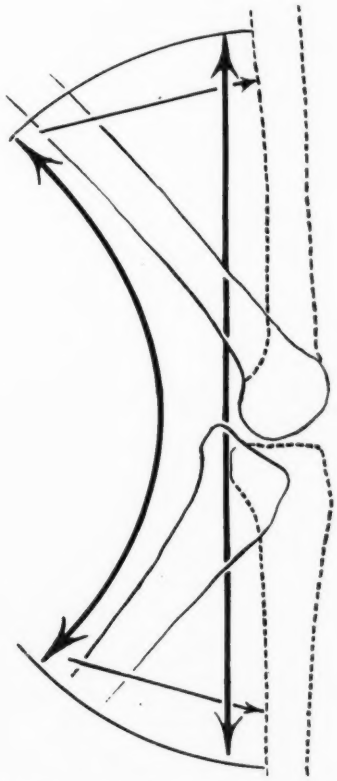

Fig. 9.—Diagramatic representation of mechanism of stretch of shortened vascular tree in correction of flexion deformities in the extremities.

anatomical principle that the main vascular channels in the extremities pass on the flexor aspects of the main joints. Flexion deformities of these joints place the vascular system in a relatively shortened state. Correction without allowing bony shortening will increase the length of the major vascular system and so produce stretch.

CASE 2.—A 15-year-old girl suffered a poliomyelitic flexion deformity of 30 degrees at the right knee and 20 degrees at the right hip (Fig. 10). To correct her knee flexion deformity a supracondylar osteotomy and tensor fasciotomy were carried out. The knee was extended and placed in a padded hip spica.

In the immediate postoperative period there was considerable complaint of pain in the limb with numbness of the toes. Sensation and movement were soon absent. The toes were described as "healthy pink" and warm, a misdiagnosis of

Fig. 10 (Case 2).—Poliomyelitic knee flexion deformity before straightening.

thrombophlebitis was made, and the patient went on to a complete Volkmann contracture.

The statement that the foot was warm and of good color despite the presence of advanced Volkmann's ischemia would appear to affirm the assertion of Kunkel and Stead that a normal blood flow to the foot does not rule out an inadequate circulation to the muscles of the calf.

CASE 3.—A 2½-year-old boy suffered a congenital lumbar meningocele with marked neurogenic equinovarus deformities of his feet. The deformity on the right was advanced and fixed. Accordingly, an extensive right medial release of the McCauley type was carried out. The foot was immobilized in the overcorrected position of calcanovalgus.

The type of preoperative deformity is indicated (Fig. 11). If the anatomical course of the posterior tibial system and its divisions is considered, it will be realized that the main vascular stem is in a foreshortened state. The postoperative position is simulated by this foot (Fig. 12). Undoubtedly, if the severe equinovarus foot is put into this calcaneovalgus position, stretch is created in the posterior tibial vascular tree.

The foot went through a series of color changes and became grossly ischemic. Initially it was described as of good color, then red and warm, then cold and red, and finally cold and cyanosed. Eight days postoperatively the cast was removed. Figure 13 is an anterior view 12 days postoperatively, after three lumbar sympathectic blocks. Figure 14 is a lateral view of the same foot.

The wrongly assuring effect of the appearance of "healthy pink" toes, or toes of "good color," is perhaps emphasized by these last two cases. Freeman and Grodins have pointed out that the circulation to the

Fig. 11.—Bilateral equinovarus deformities, greater on the right, with shortened posterior tibial vascular tree.

Fig. 12.—Foot in position of calcaneovalgus, showing mechanism of stretch of posterior tibial system.

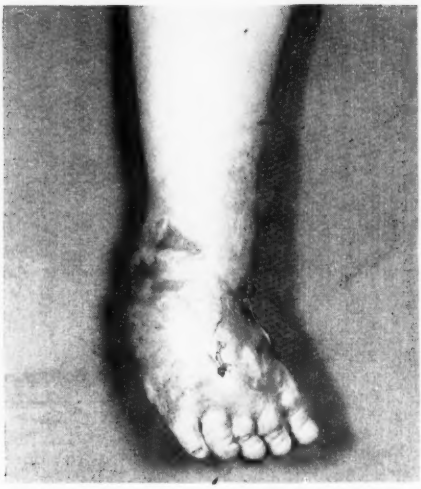

Fig. 13.—Anterior view of ischemic foot 12 days after medial release for equinovarus deformity.

Fig. 14 (Case 3).—Lateral view of same foot as in Figure 13.

skin and muscle may be independently regulated and that changes occur in the skin with opposite or no changes in the muscle. As habitually noted, pink skin is seen in an undoubtedly anoxic extremity after release of an arterial tourniquet.

Case 4.—A 20-year-old airwoman suffered a 90-degree flexion deformity of the proximal interphalangeal joint of her ring finger as a result of an old injury (Fig. 15). A replacement arthroplasty was carried out with use of a Vitallium prosthesis (Fig. 16), and the finger was extended.

On recovering from the anesthetic she complained of severe pain in the finger, and the end was cyanotic, cold, and numb to pin prick. The finger was allowed to flex, and there was a rapid return of color and sensation and disappearance of pain. Straightening of the finger caused return of symptoms and signs. She was allowed to rest the finger in the semiflexed position, and the joint became fixed in this position.

This is a further example of the same problem on a smaller scale. The prompt recognition of ischemia allowed the demonstration of the beneficial effect of early release of the stretching force through allowing the joint to flex.

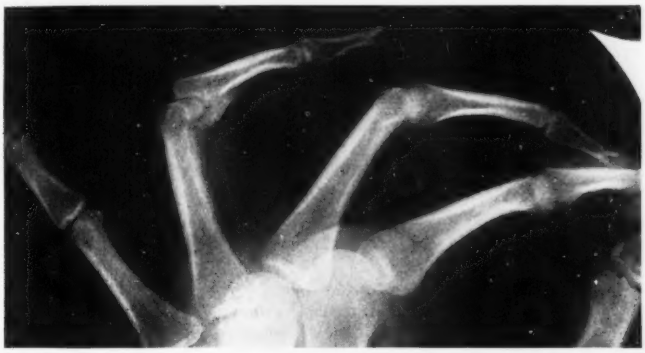

Fig. 15.—Lateral view showing preoperative flexion deformity of proximal interphalangeal joint of ring finger.

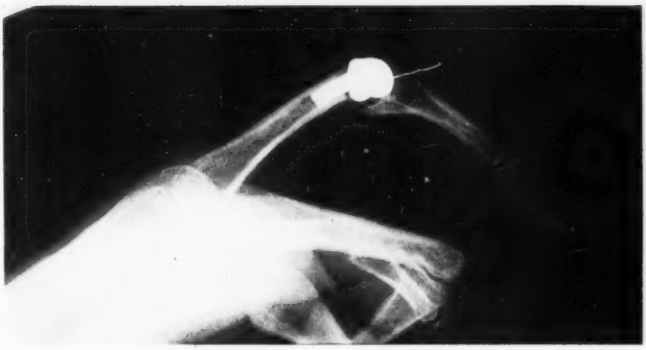

Fig. 16 (Case 4).—Postoperative radiograph showing prosthesis in position.

Conclusions

The practical clinical value of the recorded observations would appear to be the following:

Vascular spasm may be expected in any injury resulting in stretch of the vascular system.

Excessive traction in the treatment of fractures may well initiate diffuse vascular spasm.

In fractures which have allowed shortening of the vascular tree for a considerable period, spasm may be initiated when a return to normal length is made. This would suggest that the early maintenance of the normal length of a fractured limb should be established and that when shortening for a considerable period has occurred a gradual return to normal length should be made.

The ability to produce vascular stretch and subsequent severe spasm in the straightening of flexion deformities of the extremities should be realized and anticipated.

In the correction of such deformities, the early signs of ischemia should be sought and understood. The falsely reassuring signs of "good color" and warmth should not be accepted as an indication of adequate circulation. Pain, loss of movement, and absence of sensation are the reliable signs.

As soon as ischemia is recognized after the correction of a flexion deformity, stretch of the vascular system should be terminated, allowing as much return of the deformity as is necessary in an attempt to release the spasm. For the correction of a flexion deformity perhaps a procedure should be selected that will allow gradual correction of the deformity or will allow some skeletal shortening in keeping with the shortened vascular state.

Summary

An experimental investigation of vascular spasm produced by traction in the lower extremities of dogs is reported, with arteriography used as the method of study.

Four animals were studied in which stretch of the arterial system was established by lengthening one femur. This resulted in consistent diffuse bilateral spasm, more marked on the lengthened side. The spasm involved both main and collateral vessels.

In each of four dogs with a fractured femur the vascular tree was allowed to shorten for 24 hours and then was returned to normal length by plating the femur. This resulted in similar findings, with even more striking arteriographic evidence of spasm.

In each of the eight animals gross clinical signs of ischemia were present and histological studies showed the changes of limb ischemia.

Three control cases of fracture of the femur with plating resulted in no spasm.

Four clinical cases of severe ischemia following the correction of deformities of the extremities are described. The mechanism by which the correction of the deformity resulted in stretch of the vascular system is discussed.

The clinical suggestions made by these observations are considered.

DISCUSSION

DR. JOSEPH JANES, Rochester, Minn.: I should like to congratulate Dr. Simmons on his presentation. First, I congratulate him for his complete honesty in reporting cases that have shown poor results as a result of a certain method of treatment. Secondly, I congratulate him for his ingenious method of investigating the mechanism by which these poor results occur.

Arterial spasm is a problem that confronts all of us who are dealing with injuries to the extremities. Spasm of leg arteries may be produced by a distracting apparatus used in the setting of tibial fractures, such as the Watson-Jones apparatus. This has occurred in my practice. Fortunately, when the distracting force was released the spasm disappeared. Spasm also may be induced by a fragment of bone impinging on the artery.

[Slide] This slide illustrates some of the sites at which fractures or dislocations may impinge on the artery. One important one that has been left off the slide is the fracture of the upper third of the tibia, which jeopardizes the bifurcation of the popliteal artery. Another one that is left off the slide is a dislocation of the knee. Anterior dislocation of the knee certainly can involve the popliteal artery.

Spasm may be induced by concussion, as when a missile passes close to a vessel but does not actually touch it. It may be that both of these are representations of the stretch mechanism which Dr. Simmons mentioned.

As he also mentioned, myogenic spasm may at times be released by removing the cause of the spasm. Occasionally the intra-arterial injection of papaverine will help. We have observed this in cases of peripheral arterial embolism.

If the signs of spasm persist after the obvious cause has been removed, and after the injection of papaverine, administration of alcohol by mouth or intravenously, warming of the trunk, or injection with procaine of the appropriate sympathetic ganglia, then I think one must be prepared to explore the vessel.

Upon exploration of the vessel, at times the spasm may be released by bathing it with warm isotonic saline solution of 2.5% papaverine hydrocholoride. At times arterectomy may be necessary. This has been my experience in cases of supracondylar fracture in children. I have seen the distal vessels begin to pulsate, after the arterectomy.

[Slide] This slide indicates that when we explore the vessel we may not find the spasm, but something more serious. Here the intima has been damaged and thrombosis has occurred.

I should like to thank Dr. Simmons for drawing to our attention again a condition which demands early treatment in order that gangrene and Volkmann's contracture may be prevented.

DR. JOHN J. CRANLEY, Cincinnati: I should like to add my thanks to Dr. Simmons for bringing up this most important subject.

For too long it has not been appreciated that there are two types of arterial spasm. One type occurs primarily in the arteriole and is neurogenic. The other type frequently involves the major arteries and is myogenic or at least not neurogenic.

The clinical importance of this is that spasm of a large vessel due to injury, as for example a fracture, will not be relieved until the source of injury or irritation to the vessel is removed. To do this, the vessel must be explored. No amount of therapy directed at the anatomic nervous system, such as a procaine block or a sympathetic ganglionectomy, will release this type of spasm.

We are indebted to Simeone, Kinmonth, Perlow, and others for clarifying this problem. These investigators were able to demonstrate that the surest way of producing intrinsic spasm in a denervated artery is by stretching it. There are certain pitfalls that must be recognized when one is studying this type of arterial spasm.

One is that a fall in blood pressure will cause the artery to decrease in size, and a change in size alone is not necessarily indication of spasm.

For example, the caliber of the small intestine will be diminished distal to a point of obstruction, but that does not mean that it is in spasm; it is small because it is empty. So, too, a vessel distal to the point of obstruction may be empty and therefore small, but that does not indicate spasm of the entire distal arterial tree.

I believe that the evidence available today indicates that this type of spasm is segmental, not diffuse, and that anatomic evidence of a reflex arc is lacking.

DR. HAROLD LAUFMAN, Chicago: I should like to call attention to some other causes for this type of spasm.

In some instances it may confuse a diagnosis, if not injure the patient's condition.

[Slide] These are slides of one patient who underwent aortography, and here you see the aortograph, with the patient in the prone position under local anesthesia. He was a very apprehensive person despite his premedication, and he reacted with intense pain as the dye was injected. We got no fill below the common femoral artery because of severe spasm.

[Slide] One week later this man was given general anesthesia and the arteriogram was repeated. It shows a significant block in an otherwise well-filled arteriogram. The lesion was very amenable to bypass surgery, which was done with success.

DR. E. H. SIMMONS, Toronto, Ont., Canada: I should like to thank the discussers for their interest in this subject. I do not wish to prolong the discussion, but there are a few words I should like to add.

First, concerning Dr. Cranley's remark that this is not a diffuse spasm: Localized segmental spasm may occur in response to direct trauma to a vessel, but the spasm in these cases was initiated by stretch, and there was a diffuse spasm of both main and collateral vessels, and the collateral involvement may well be the more important factor. The opposite extremity is involved. This may explain the appearance of Volkmann's contracture, as has been reported, in the opposite lower extremity. In 1951 Thomson and Mahoney reported 24 cases of Volkmann's contracture in the lower extremity. Fourteen were acute cases of ischemia, and thirteen of these followed fractures of the femur treated with traction. One case, a little girl, suffered a fractured femur treated by "Gallow's" type of suspension. The fractured limb progressed very satisfactorily, but she developed a "full-blown" Volkmann's ischemia in the normal extremity.

[Slide] This is a possible explanation of how spasm reaches the opposite extremity (Fig. 17).

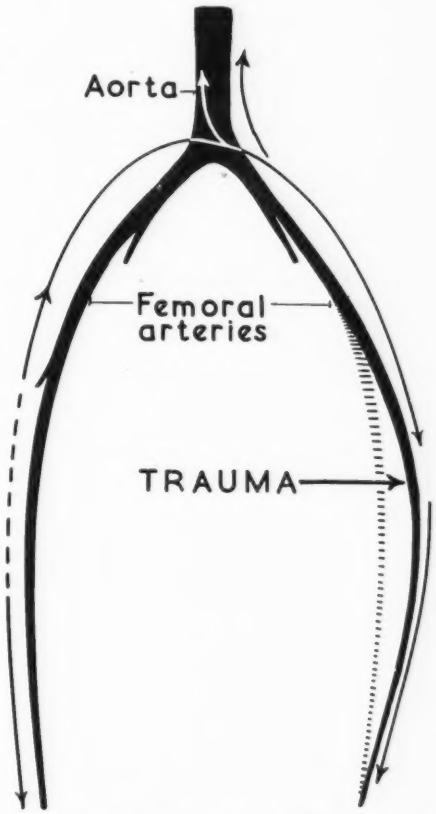

Fig. 17.—Suggested mechanism for myogenic basis of contralateral vascular spasm; stretching force transmitted around aortic bifurcation to opposite lower limb.

You are acquainted with the various theories as to the nature of the spasm. I agree with Dr. Cranley that it is most probably a myogenic spasm of the main vascular tree. It is felt that trauma may initiate spasm by producing stretch. Stretch of the arterial system in one lower extremity, as indicated, will create pull in an upward and downward direction. The upward pull will be resisted by a strong aorta, and as a result will be

transferred in part at least around the bifurcation to the opposite lower limb. As the distal ends of the vascular systems are fixed, stretch will occur in both extremities. Although this is not a proved fact, it is suggested as a working hypothesis.

Secondly, in fractures of an extremity, it may be that the fracture spiculum can bowstring an artery, producing stretch, as has been suggested by Cohen and others.

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Preservation of Rectum in Familial Polyposis of the Colon and Rectum

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The operative procedure to be used for familial polyposis of the colon should be selected mainly on the bases of the extent of involvement of the mucous membrane at the time treatment is instituted, the apparent rate of progression of the disease, and the presence or absence of cancer. Familial polyposis is usually progressive. New polyps form, and in any one of them cancer may evolve. The ordinarily progressive nature of the disease has dictated the belief that total colectomy with proctectomy is the only means of freeing the patient from the risk of cancer. The surgical management of polyposis of the colon up to 1948 was thoroughly reviewed by Hoxworth and Slaughter [1] and will not be repeated. Ravitch * showed that satisfactory bowel function followed anastomosis between the terminal ileum and the anus, thereby permitting total coloproctectomy to be accomplished without abdominal ileostomy. Best [4] has used this operation with satisfactory results. Devine [5] modified it by leaving the rectal musculature while removing the rectal mucosa; the ileum is drawn through the denuded muscular tube of rectum and joined to the anal skin. This operation avoids the pelvic mobilization of the rectum and better preserves the attachments of the levator ani muscles and pelvic nerves.

Because of the different clinical situations which are encountered, and the difficulty in predicting the rate of progression of the disease, we believe that a single surgical procedure cannot meet the requirements in all patients. Under particular circumstances we have continued to employ total colectomy and ileoproctostomy and thereafter to control polyps that may form subsequently within the rectum by endoscopic removal and fulguration. In this paper we will review our experience with this, the Lockhart-Mummery procedure,[6] in order to determine whether the results justify its continued use. The series consists of 13 cases, 11 having familial polyposis and 3, multiple nonfamilial polyposis. Eleven were operated upon at the Barnes Hospital, and two, by Dr. Robert M. Moore, at the John Sealy Hospital in Galveston, Texas. All cases were operated upon between 1946 and 1955; therefore, the period of follow-up is brief.

Report of Cases

CASE 1.—A 47-year-old white woman was first admitted to the Barnes Hospital in 1947 with a history of diarrhea with blood and mucus in the stool. In 1938 resection of the sigmoid had been performed because of a cancer in that area. Barium enema revealed a filling defect in the ascending colon. On June 12, 1947, right hemicolectomy, including 20 cm. of the distal ileum, was performed. Pathology: infiltrating carcinoma of ascending colon with lymph node metastases. Multiple benign polyps of ascending and transverse colon.

The postoperative course was uneventful. Adequate family history finally revealed that two siblings, two nieces, and a grandniece had polyposis of the colon. On Dec. 7, 1948, the remaining colon was removed and an end-to-side ileosig-

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moidostomy was performed. Numerous benign adenomatous polyps were present. The postoperative course was uneventful. At the time of discharge she was having two to three soft stools per day. In the four succeeding years rectal polyps were removed on three occasions.

In April, 1951, cholecystectomy was performed; exploration revealed no evidence of cancer, but an unsuspected polyp was found in the pouch of sigmoid above the end-to-side anastomosis. The pouch was removed, and the anastomosis was converted to an end-to-end ileoproctostomy. One year later pulmonary metastases developed, with death in August, 1952. Autopsy was not performed.

CASE 2.—A 26-year-old white woman, the niece of the patient in Case 1, was admitted to the Barnes Hospital on June 6, 1948, with a history of intermittent bloody diarrhea for at least six years. Cysts of Endamoeba histolytica had been found in the stool five years previously, and treatment for amebiasis had been given. Family history was as in Case 1. Sigmoidoscopy and barium enema revealed multiple small polyps. On July 9, 1948, a right colectomy and end-to-side ileosigmoidostomy was performed, including 5 cm. of terminal ileum. On July 27, 1948, the remaining colon to the anastomotic site was removed. Pathology: multiple polyposis, benign. During the postoperative period mild abdominal cramps were experienced; these subsided on the 10th postoperative day. At the time of discharge she was having two to three soft stools per day. In the period since operation she has been readmitted 12 times for fulguration of polyps. No evidence of malignant change has been found.

CASE 3.—A 16-year-old white girl, the daughter of the patient in Case 2, was admitted to the Barnes Hospital on July 13, 1953, for colectomy. Examination had been carried out in the absence of symptoms because of the family history of polyposis. The diagnosis of polyposis was established by sigmoidoscopy and barium enema. On July 20, 1953, total colectomy, including 5 cm. of the distal ileum, was performed. Continuity was reestablished by end-to-end ileoproctostomy. Pathology: multiple adenomatous polyps, benign. The postoperative course was uneventful. At the time of discharge from the hospital she was having four to five soft stools per day. Subsequently this has decreased to three to four. Polyps have been removed from the rectum three times. Her health is good, although she tends to be obese.

CASE 4.—A 48-year-old white woman was admitted to Barnes Hospital on Dec. 8, 1949, with a three-month history of left lower quadrant cramping pain. Four days prior to admission she passed fresh and clotted blood per rectum. The family history revealed the following: Her father died at age 60 of "carcinoma of liver"; one half-sister and one half-brother, both on the paternal side, had multiple polyposis of the colon. Barium enema revealed an obstructing lesion of the sigmoid colon. At operation multiple polyps of the colon were found. The distal 7 cm. of ileum and the colon to the peritoneal reflection were removed, and an ileostomy was performed. Pathology: adenocarcinoma of the sigmoid, multiple polyposis of the colon. Two of twenty-eight lymph nodes examined contained metastatic carcinoma.

On Feb. 13, 1950, sigmoidoscopy revealed a polyp at 12 cm. which on biopsy was reported as benign. On March 17, 1950, a second operation was performed, with excision of all but the distal 8 cm. of rectum and end-to-end ileoproctostomy. The rectal segment removed contained five polyps varying from 2 mm. to 2 cm. in size. No carcinoma was found. On March 25, 1953, a subdiaphragmatic abscess was drained, and on March 27, 1955, incision and drainage of a pelvic abscess was performed. The patient had an uneventful recovery following this. Polyps have been removed from the rectum on three occasions since operation. At present she is in good health, has four to five formed stools per day and one stool at night.

CASE 5.—A 26-year-old white housewife was admitted to Barnes Hospital on Nov. 14, 1949, with a three-year history of occasional mild abdominal cramping pain. The patient's mother and brother were both known to have multiple polyposis. Barium enema showed multiple polyps of the colon. Sigmoidoscopy was negative. On Nov. 22, 1949, a total colectomy with end-to-end ileoproctostomy was performed. Fifteen centimeters of terminal ileum was removed with the colon. Pathology: multiple polyps; one polyp in the sigmoid showed adenocarcinoma Grade 1 in the tip. There were no lymph nodes involved.

Postoperatively the patient developed nausea, vomiting, abdominal cramping pains, and distention. On Dec. 9, 1949, a laparotomy was performed, with freeing of adhesions and formation of a temporary ileostomy. She then had an uneventful recovery, and the ileostomy was closed elsewhere. The patient was last seen in follow-up examination in October, 1953. She was in good health, with two formed stools per day. Rectal and proctoscopic examination were negative. Information from her physician, who has examined her biennially, reveals that no further polyps have been observed.

CASE 6.—A 31-year-old white woman, the sister of the patient in Case 7, was admitted to Barnes Hospital on June 10, 1946, with a history of intermittent passage of bright red blood per rectum for five years. Sigmoidoscopy revealed multiple polyps beginning at 19 cm. Biopsy revealed adenomatous polyp. X-rays revealed multiple polyps of the colon. On July 11, 1946, a total colectomy, including five in. of terminal ileum, was performed, with anas-

tomosis of ileum to the rectum at the rectosigmoid junction. The postoperative course was uneventful. Pathology: multiple adenomatous polyps of colon. Proctoscopy to the level of the anastomosis, 10 cm., has been performed at regular intervals since operation. Fulguration of small rectal polyps was required on five different occasions. Patient was last seen on Feb. 11, 1956, at which time she was in good health, having one formed stool per day. She states she has to watch her diet to avoid excess weight gain.

CASE 7.—A 24-year-old white man, whose father died of carcinoma of the cecum and whose sister underwent total colectomy for multiple polyposis, was admitted to Barnes Hospital on Nov. 27, 1948, with a three-year history of intermittent attacks of diarrhea with passage of bright red blood followed by tarry stools. Attacks lasted three to four days, occurred three to four times per month. Sigmoidoscopic examination revealed several pedunculated polyps beginning at 20 cm. Biopsy of a polyp was reported as "benign polyp." Barium enema was "not notable except for increased tonicity." On Dec. 1, 1948, a total colectomy and ileoproctostomy was performed. The specimen included the terminal 12 cm. of the ileum and the large bowel to the pelvic brim. Pathology: multiple polyposis, benign.

In the postoperative period the patient had mild cramping abdominal pains which subsided over a three-week period. At the time of discharge, he was having one to two soft stools per day. He rapidly gained weight to 200 lb., a 25 lb. weight gain. He was followed up to 1953 but since that time has not returned. Correspondence reveals that he is asymptomatic.

CASE 8.—A 67-year-old white woman was admitted to Barnes Hospital on April 6, 1948, with a one-month history of passage of bright red blood per rectum and intermittent cramping and lower abdominal pain. No family history of polyposis or cancer of the colon was obtained. Sigmoidoscopy to 25 cm. was negative. Barium enema showed a filling defect in the sigmoid colon. On April 11, 1948, repeat sigmoidoscopy revealed a polyp of the rectum at 12 cm., which was removed and reported as adenomatous polyp. On April 14, 1948, a sigmoid colectomy was performed; recovery was uneventful.

Pathology: Examination of the specimen revealed a 35 cm. segment of colon with a polypoid adenocarcinoma of the sigmoid colon invading the muscular layer. No lymph nodes were involved.

She was followed closely in the tumor clinic and did well until October, 1953, when a routine barium enema showed a 2.5 cm. polyp in the hepatic flexure. On Oct. 9, 1953, she had a total colectomy with end-to-end anastomosis of the ileum to the rectum. A 15 cm. segment of terminal ileum was removed. Since then her course has been uneventful; no further polyps have been found.

Pathology: adenomatous polyps in the hepatic flexure and in the transverse colon.

CASE 9.—A 2½-year-old white boy was admitted on July 24, 1947, because of protrusion of a bleeding rectal polyp. The polyp was excised, and the patient was discharged after 24 hours with a diagnosis of adenomatous polyp of the rectum. The family history was negative, but a brother later developed polyposis. The patient was readmitted on May 4, 1948, with a history of recurrent rectal bleeding. Proctoscopic examination revealed seven small polyps and one large polyp of the rectum. All polyps but one at 8 in. were removed. The patient was discharged with the diagnosis of multiple benign polyps of the rectum. Pathological diagnosis was rectal polyps, benign. He was again readmitted on Feb. 26, 1953, with history of intermittent lower abdominal cramps and passage of bright red blood per rectum. Barium enema one month prior to admission showed multiple polyps of the colon with a large filling defect of the right colon. Physical examination revealed a well-developed well-nourished white boy. Two small polyps were palpated on the posterior wall of the rectum. On Feb. 27, 1953, the patient had total colectomy with end-to-end ileoproctostomy. The length of ileum was 6 cm. Multiple polyps were palpated throughout the entire colon. Postoperatively the patient had moderately severe cramping abdominal pain lasting three weeks. He had three to four loose stools per day. Proctoscopic examination showed no residual polyps, and none have appeared in the course of follow-up. Pathology: 15 polyps, most on long stalks, up to 4 cm. long, size varying up to 2 cm. in diameter; no carcinoma found.

CASE 10.—A 3½-year-old white boy, the brother of the patient in Case 9, was admitted on May 4, 1948, with history of intermittent rectal bleeding for two weeks. At age one year he had had a rectal polyp removed for rectal bleeding. The family history revealed that one brother had multiple polyps. No other familial history of polyposis or cancer was obtained. Physical examination revealed a well-developed well-nourished white boy with two polyps palpable on rectal examination. On May 5, 1948, the patient had proctoscopy with removal of two polyps, 2×1.5×1.5 cm., about 3 in. above the anus. The patient was discharged with diagnosis of benign polyps of the rectum.

He was readmitted on July 19, 1950, with history of recurring rectal polyps and bleeding from the rectum. On physical examination rectal examination was negative. Proctoscopy was also negative.

The patient was readmitted for the third time on March 16, 1955, with intermittent passage of

bright red blood from rectum. Barium enema one week prior to admission showed multiple polyps of transverse and sigmoid colon. Physical examination was negative; rectal examination, negative. On March 18, 1955, he had colectomy to the rectosigmoid junction, with removal of 5 cm. of terminal ileum and end-to-end anastomosis of ileum and rectal stump. Pathology: Six pedunculated and one sessile polyp, varying up to 3 cm. in size; no carcinoma; 146 nodes were examined, 146/146 showing hyperplasia. The postoperative course was uneventful. The patient had two semiformed stools per day at discharge, on the 10th postoperative day. There has been no evidence of new polyp formation in the rectum.

CASE 11.—A 13-year-old white boy was admitted to St. Louis Children's Hospital on Oct. 5, 1954, with a history of lower abdominal cramping pain and intermittent bloody diarrhea for five months, with nausea, vomiting, and a mass in the right lower quadrant for one week prior to admission. The patient had had protrusion of the rectum every two to three months for two years. The paternal aunt and grandfather had carcinoma of the colon. The father and one brother were later found to have a single rectal polyp each. Physical examination revealed a thin undernourished white boy, weighing 65 lb., with a firm nodular movable tender mass in the right lower quadrant. Rectal examination was negative. Barium enema revealed an obstructive intraluminal mass in the sigmoid which was interpreted as intussusception with multiple polyps of the sigmoid and rectosigmoid distal to the obstruction.

On Oct. 6, 1954, the patient had a total colectomy to the upper rectum, including 5 cm. of ileum, and an end-to-end ileoproctostomy. Polyps were palpable from the sigmoid to the cecum, with four areas showing serosal changes compatible with malignant infiltration. During the postoperative course he had fever and abdominal cramps, which gradually subsided. There were four to five loose stools per day. Six months after operation he was readmitted for removal of four small rectal polyps.

Pathology: Multiple polyps from 5 mm. to 5 cm. in size, pedunculated, with a few small sessile polyps. Microscopic sections revealed five of the polyps to show adenocarcinoma with invasion of the serosa in one area and nerve sheath invasion in another. Of 136 nodes, 2 contained metastatic cancer.

CASE 12.—A 6-year-old white boy, on Oct. 18, 1949, had a resection of terminal ileum and entire colon to the distal sigmoid; one adenomatous polyp was removed from the rectum. The resected colon contained 18 additional polyps. Pathology: Benign adenomatous polyps. After operation there was a troublesome diarrhea for several weeks, which then became intermittent with periods of severe abdominal cramps and threatened obstruction. Three months after operation, a laparotomy was performed for acute intestinal obstruction caused by adhesions in the pelvis with appearance that peritonitis had followed operation. Since that time there have been no diarrhea and no threats of obstruction. The child has eaten a normal diet since the second operation, with one formed stool daily and a second stool only very occasionally. Annual proctoscopic examinations have failed to reveal any additional polyps.

CASE 13.—A 3½-year-old white girl on Dec. 29, 1950, had the terminal 4 in. of ileum and entire colon resected to the distal sigmoid. One adenomatous polyp was removed from the rectum. The resected colon contained 16 polyps. Pathology: Benign adenomatous polyps.

There was no significant diarrhea following operation, the child never having more than three bowel movements daily. In the ensuing time there has been no diarrhea, but only two normal stools during the 24-hour period. Annual proctoscopic examination has failed to reveal subsequent development of any rectal polyps.

Selection of Patients for Ileoproctostomy

It is necessary to have complete understanding and assurance of cooperation on the part of the patient if the rectum is to be preserved in familial polyposis, because regular follow-up examinations must be carried out, with prompt removal of polyps as they appear. If the surgeon is doubtful about the patient's cooperation, we believe that no consideration should be given to preservation of the rectum. Ileoproctostomy may be employed when there are no polyps within the rectum or their numbers are small (Fig. 1), but then it should be used only when the greater part of the rectal mucosa is normal. Cancer of the rectum, large sessile polyps, or total involvement of the mucous membrane of the rectum, as in Figure 2, are obvious contraindications to the preservation of the rectum.

Technical Considerations

If the rectum is to be preserved, the risk of new polyp formation or of cancer can be quantitatively reduced by leaving a short rectal segment. In males extensive mobilization of the rectum is a potential source

Fig. 1. (Case 6).—Gross specimen, showing variable distribution of polyps.

of injury to pelvic sympathetic nerve fibers, which could result in impaired sexual function. The danger of perforation resulting from the fulguration of polyps is increased if any of the intraperitoneal portion of the sigmoid colon is preserved. An end-to-side ileoproctostomy leaves a blind pouch which is visualized with difficulty during proctoscopic examination. An end-to-end ileoproctostomy at the level of the peritoneal reflection is technically simple and safe, leaves a short segment for later management, and avoids pelvic dissection as well as a blind pouch. This is therefore the technique which we believe should be used.

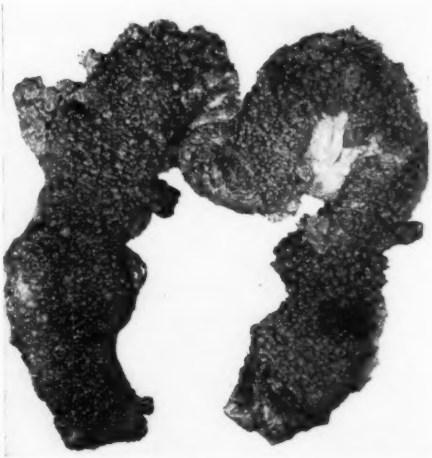

Fig. 2.—Total involvement of mucous membrane, unsuitable for ileoproctostomy.

Operative Mortality and Morbidity

There has been no operative mortality. Three patients had serious postoperative complications. In Case 4 a subdiaphragmatic and pelvic abscess occurred. Recovery followed drainage. In Cases 5 and 12 simple mechanical obstruction due to an adhesive band developed. Both were surgically corrected without further sequelae. Less important, although distressing, symptoms, consisting of abdominal cramps, occurred in the early postoperative period in four patients (Cases 2, 7, 9, and 11). The maximum duration of these symptoms was three weeks.

Postoperative Bowel Function

Lillehei and Wangensteen [7] reviewed the postoperative bowel function of 73 patients in whom total colectomy was carried out for a variety of lesions including polyposis. They found the length of terminal ileum which had been removed to be of greater importance than the length of rectum which was preserved. The critical length of distal ileum was found to be 30 cm. Kremen, Linner, and Nelson [8] found that an intact ileocecal valve protected against the development of diarrhea in dogs subjected to removal of large portions of the small bowel. Lillehei and Wangensteen [7] in their study found that this was also true in humans.

The length of terminal ileum included in the resection in the patients in the series varied from 5 to 20 cm. The length of rectum which was preserved varied from 8 to 25 cm. With one exception (Case 9), all patients in the present report have normal continence, with one to five stools of variable consistency each day. The one patient who does not have normal bowel function had 6 cm. of terminal ileum removed and 8 cm. of rectum preserved. He has normal sphincter tone, his stool is watery or semiformed, and during the day he has normal sensation and continence.

During the night, however, he has occasional involuntary evacuations, with no apparent improvement in the three years which have elapsed since operation.

No dietary restrictions have been imposed or have been voluntarily assumed by any of these patients. They are all as susceptible to epidemic diarrhea as are persons with an intact colon, but their susceptibility does not appear to be increased. The fulguration of polyps, particularly if extensive, is attended by transient diarrhea.

The effect of pelvic dissection of the rectum on sexual function in males is a subject of great interest, because of the frequency with which this manipulation is carried out in current surgical practice. The operation under discussion should not effect any change in sexual function, since the rectum is not mobilized. In the one adult male in whom the operation has been performed, sexual function is normal. The three male children have not reached sufficient age to allow evaluation of sexual function.

Difficulty in Postoperative Management of the Rectal Segment

Cancer of the rectum has not developed in any patient up to the time of this report. One patient is dead of cancer of the colon (Case 1), but the rectal segment remained free of cancer up to the time of death. The other 12 patients are alive and in good health. With one exception, they have been faithful in submitting to regular examination and treatment. The need for endoscopic removal of polyps has been variable. Four patients have not developed polyps following colectomy. In the Table are listed the years since operation and the number of times it has been necessary to remove polyps in the remaining nine patients. The greatest difficulty has been experienced with Case 2, who has required 12 fulgurations of polyps over a seven-year period. Despite the frequency and extent of fulguration which has been necessary, the rectum remains pliable, although some scarring is visible in the mucosa. Bowel function remains good, and it has not been considered necessary to advise removal of the rectum.

Postoperative Fulguration of Rectal Polyps

Case	Years Since Operation	Fulgurations Required, No.
1	4	3
2	8	12
3	3	3
4	5	3
5	7	1
6	10	6
7	8	?
8	8	1
11	1½	1

The patient who has not been followed by the operating surgeon is considered to be at greater risk than is desired when this operation is performed. This patient has not been examined since 1953; he has been contacted and states that he is free of symptoms, but he has not been willing to return for examination or to see a surgeon in the city in which he resides.

When polyps are removed through the proctoscope it is essential that all tissues removed be submitted to pathological examination. Pedunculated polyps are removed with the cautery snare, which does not interfere with pathological interpretation. Small sessile polyps are removed with the biopsy forceps; the base is then fulgurated to control bleeding and to destroy any remaining abnormal tissue. No serious bleeding, perforation, or other complications have resulted from the procedure in this group of patients.

Growth and Development of Children Following Colectomy

In a study of long-standing ulcerative colitis in children by Thurston and Holowach [9] it is reported that after colectomy improvement in physical status occurs, although normal levels of growth are never reached. Using height, weight, and age data plotted on the Wetzel Grid, we can find no evidence that a decrease in the rate of development occurred or that physique was impaired as a result of colectomy in the five children in this series. On the contrary, in one patient (Case 11), in whom chronic blood loss and recurrent intussusception resulted in impaired development, marked

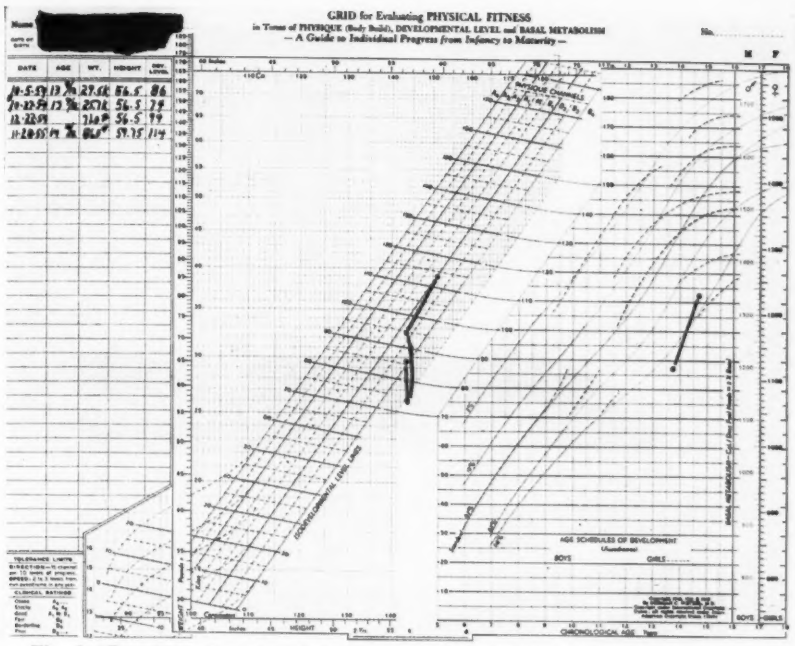

Fig. 3 (Case 11).—Growth and development. Growth failure and improvement resulting from colectomy.

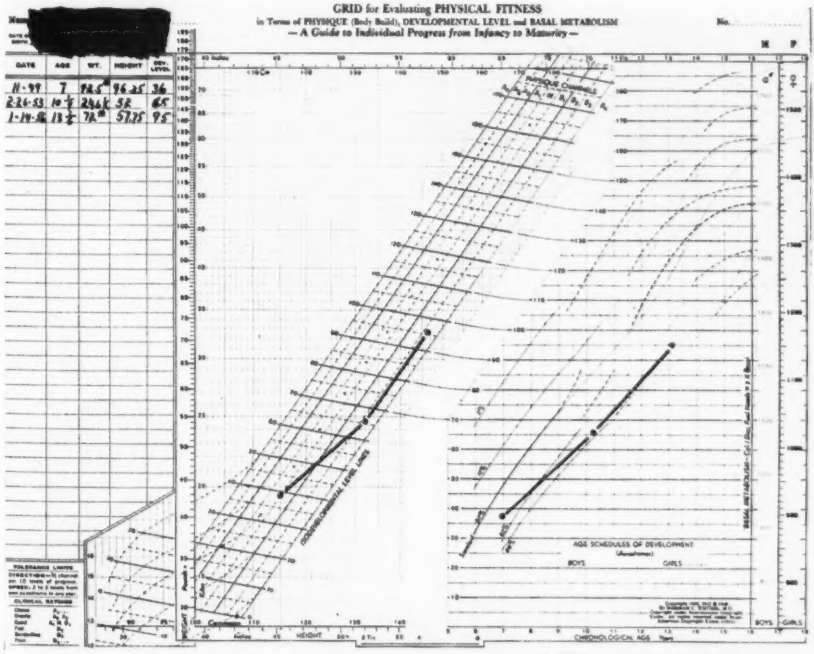

Fig. 4 (Case 9).—Growth and development. This boy is tall and slender, but his physique has been relatively unchanged.

improvement is noted in the year since colectomy was performed (Figs. 3 and 4).

Comment

The treatment of diffuse polyposis in infancy and childhood is at times perplexing by virtue of the fact that many colonic and rectal polyps encountered in infancy and early childhood have rather unusual clinical and pathological features.[10] While true adenomatous polyps similar to those seen in adults may occur in this age group, another form exists. This form of polyp usually exists singly, but occasionally, as in Cases 9 and 10 of this series, they may be multiple and occur in different segments of the colon and rectum in siblings. Grossly these polyps of childhood tend to be pedun-

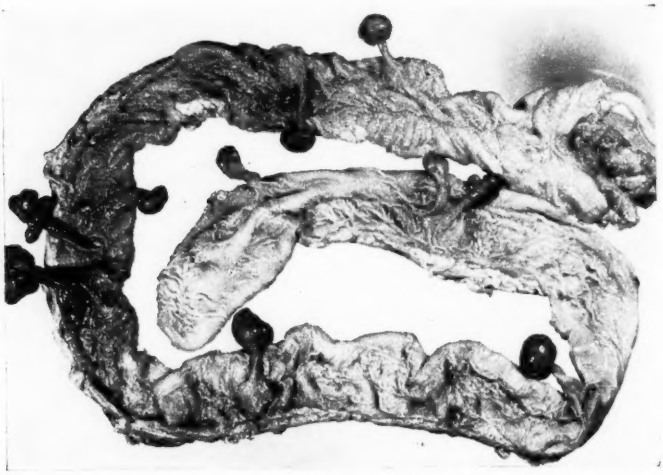

Fig. 5 (Case 9).—Gross specimen, all polyps "juvenile" in type.

Fig. 6.—Photomicrograph; reduced from mag. ×10. "Juvenile" polyp. Note absence of surface epithelium, cystic dilatation of glands, and lack of resemblance to the usual adenomatous polyp of the large bowel.

culated, have smooth cherry red surfaces, and bleed easily on trauma (Fig. 5). They are covered by a single layer of mucus-producing columnar cells with basally oriented nuclei (Fig. 6). Frequently the covering layer is absent and a vascular loose connective tissue stroma is exposed to the fecal stream, predisposing to melena. Interspersed within the stroma are dilated glands lined by normal colonic mucosa; the dilatation of the glands at times reaches cystic proportions. The appearance of the polyp is more suggestive of an inflammatory than of a neoplastic origin; however, enigmatically, the intestinal mucosa between the polyps shows no evidence of inflammation. Lischer and Schwarz † reviewed 40 cases of this type of polyp. They found that recurrence and new polyp formation following removal was rare and that carcinoma did not develop in a single case. Consequently, when a polyp of this type is encountered and diagnosed by biopsy, a conservative approach, namely, local excision, is indicated. However, when they are numerous and spread throughout the bowel colectomy may be necessary to control hemorrhage and intussusception, but the rectum should not be removed for these nonadenomatous "juvenile" polyps. On the contrary, ileoproctostomy for true adenomatous polyposis, we will grant, is a risky procedure and is attended by inconvenience to the patient as well as the hazard of the later development of rectal cancer. The patients reviewed here illustrate that the hazard is minimal within the short time period of observation. However, these patients have a long life expectancy and should one of them die of cancer ileoproctostomy will perforce have been ill-chosen. Nevertheless, until the weight of the danger of cancer can be assessed relative to the greater morbidity attendant upon anal ileostomy, one should not be overly critical of the use of ileoproctostomy for familial polyposis in carefully selected, cooperative patients.

†Lisher, C. E., and Schwarz, H.: Unpublished study, personal communication to the authors.

Summary and Conclusions

Thirteen patients with polyposis of the colon are presented, all of whom have been treated by endoscopic control of rectal polyps combined with total colectomy and ileoproctostomy.

The selection of patients for this operation is made on the basis of estimation of their ability to cooperate, relative freedom of the rectum from disease, or the presence of "juvenile" polyps.

The use of end-to-end anastomosis between rectum and ileum is stressed.

There has been no operative mortality; morbidity consisted of intraperitoneal abscesses in one case and simple mechanical intestinal obstruction in two cases.

Bowel function is excellent in 12 patients, but only satisfactory in 1 patient, owing to the occurrence of involuntary stools at night in this patient.

Difficulties in the management of polyps in the rectum are discussed. Pathological examination of all abnormal tissues is emphasized.

Colectomy does not appear to retard growth or physical development when carried out in childhood.

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Behavior and Fate of Ileal Segments Interposed in the Left Colon

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Segments of small bowel have been used in a variety of ways by surgeons and experimentalists as substitute and repair structures.[1] Several investigators have utilized ileum to replace resected segments of the left colon both in experimental animals and, more recently, in humans.* Consideration of the problems of colon surgery and, more specifically, of surgery of malignant lesions of the left colon suggest that the use of ileal grafts might find clinical application. Current concepts of adequate cancer surgery include high vascular ligation and wide mesenteric resection. There are situations when adherence to these concepts necessitates the formation of a permanent colostomy even though the location of the lesion justifies resection with primary anastomosis. This situation may exist when mobilization of the hepatic flexture is impractical or excessively difficult or, as pointed out recently by Baker,[9] when anomalies of the middle colic vessels make mobilization of the promimal transverse colon into the pelvis impossible. In such a situation one is faced with the choice of compromising cancer surgery or sacrificing an otherwise preservable sphincter mechanism. Use of a pedicled ileal graft may in these cases permit both adequate surgery and preservation of the anal sphincter. Descriptions of the technique of utilizing ileal grafts in the colon have been published,† but little has been written concerning the functional behavior and anatomical changes of the graft. An evaluation of the interposed ileal segment was therefore undertaken in order to determine the functional and anatomical changes which occur in the segment and in the colon as a functional unit.

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Methods

Eleven apparently healthy adult mongrel dogs whose weights ranged from 8 to 19 kg. were used. The animals were dewormed and observed preoperatively for a minimum of two weeks. During the studies the animals were individually caged and were maintained on a diet of cooked horsemeat, commercial dog food, and water ad libitum. For 48 hours prior to surgery, food was withheld, and the animals were given 30 gm. of magnesium sulfate and 1 gm. of neomycin. This was repeated 24 hours prior to surgery. Water was withheld during the 12 hours immediately before operation. The animals were anesthesized with intravenus pentobarbital sodium in a dose of 15 mg. per kilogram of body weight. Anesthesia was maintained with an ether-oxygen mixture delivered through an intratracheal tube. The abdomen was entered through a midline incision. A segment of terminal ileum varying in length from 10 to 35 cm. was selected. It was isolated from the intestinal tract by transection of the bowel at the proximal and distal ends of the selected segment. In choosing the ileal segment, the number of arcades utilized depended entirely upon the length of small intestine necessary for the graft. There was no evidence that a single arcade is not adequate, and in several cases such a single arcade was used with no evidence of impaired viability of the segment. Great care was

† References 6-8.

taken to mark the two ends of the transplant properly so that it could be placed isoperistaltically in the colon. Intestinal continuity was restored by end-to-end anastomosis of the divided ileum, and the rent in the mesentery was carefully closed. A segment of distal colon was then resected, and the ileal graft with intact blood supply was swung into position in the defect created in the left colon. Colonic continuity was then established by end-to-end anastomosis of the colon to the ileal graft, with use of a two-layer open suture technique. The edges of the mesenteric pedicle of the ileal transplant were sutured to the parietes in order to avoid the formation of an intraperitoneal band which might lead to an intestinal obstruction (Fig. 1).

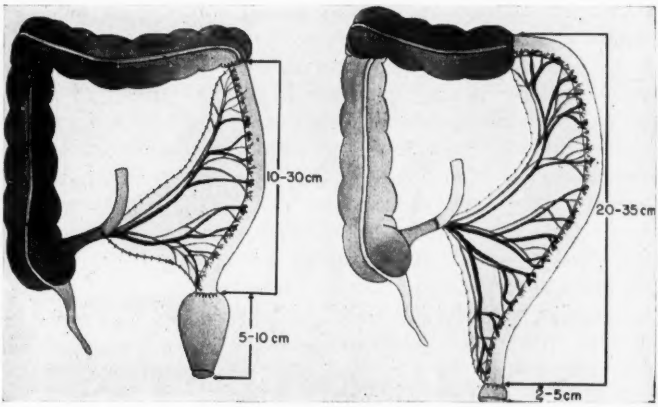

Fig. 1.—Schematic diagram of operative procedures carried out. In each instance the sphincter mechanism is preserved and varying lengths of the left colon are replaced with pedicled ileal grafts. Anatomical configuration of the human colon is utilized for easier visualization of problems encountered.

In six animals the operative procedure was modified to permit the ileal segment to be placed in close proximity to the anus. With the exception of the distal ileorectal anastomosis, the abdominal procedure was carried on as described. The rectum was then mobilized down to the sphincter and everted through the anus. The distal end of the ileal segment was then drawn through the everted rectum and the distal anastomosis performed from below. In pulling the ileal graft through the everted rectum for transanal anastomosis, great care must be taken to avoid excessive traction, as it is possible to avulse the mesentery and devascularize portions of the graft. This lesson was learned at the expense of the first operative mortality. The distal rectal cuff varied in length from 2 to 5 cm. Thus in all cases the anal sphincter mechanism was preserved together with a short but varying length of the distal rectum (Fig. 1). Postoperatively the dogs were given water ad libitum. On the second day, increasing amounts of cooked horsemeat were provided; by the fifth day after operation all dogs were on standard kennel diet. The animals were given intramuscular injections of 300,000 units of procaine penicillin G and 0.5 gm. of streptomycin daily for four days following operation. Observations were made on the frequency of defecation, consistency of the stool, dietary habits, body weight, and general health of all animals. At intervals varying from 2 weeks to 12 months, barium was instilled into the rectum, and careful fluoroscopic observations were made on the ileal segment and the adjacent colon. Radiographs of the observed phenomona were made. At similar intervals observations of the motor behavior of the ileal segment in the left colon were made by placing balloons in tandem into the colon above the graft, into the graft itself, and into the rectum distal to the graft. Simultaneous pressure recordings were then made on a standard kymograph, with use of a water-filled system. At varying intervals certain of the animals were subjected to exploratory laparotomy and observation of the segment in situ were made. Other animals were killed. In the postmortem examinations care was taken to obtain specimens for microscopic examination of normal colon, normal ileum, and varying portions of the interposed segments, as well as all suture lines.

Results

There were no postoperative deaths or complications in the group of five animals in which all anastomoses were performed intra-abdominally. In the second group, of six animals, in which the distal anastomosis was performed by the pull-through technique, there were two postoperative deaths and two further animals died several months later of unrelated causes. In these two

cases, death could not be attributed to the procedure and the animals survived for a sufficient period of time to permit study.

(*a*) *Immediate Postoperative Deaths.*—One long-haired animal died of intestinal obstruction on the fourth postoperative day. At the site of the ileoileal anastomosis a trichobezoar which completely obstructed the lumen was found. Autopsy of the other animal disclosed gangrene and perforation of the transplanted ileal segment at the distal ileocolic anastomosis. The vascular supply of the distal end of the graft had been avulsed during the performance of the pull-through anastomoses. The two unrelated deaths occurred at eight and nine weeks after operation and apparently resulted from infectious diseases.

(*b*) *Stool Habits.*—Postoperatively, diarrhea developed in all the animals. Stools remained liquid for varying lengths of time, with return to normal requiring an average of six days in the group of animals in which a long rectal stump remained. The longest time for return to normal stool consistency and number was required by the group of animals in which the pull-through technique was used. With the shorter rectal stump, diarrhea persisted for an average of four weeks and in two of the animals normal consistency was not achieved until six weeks after operation. The return to normal number of stools roughly paralleled the return of the stools to normal consistency. The act of defecation was not impaired.

(*c*) *Nutrition.*—Dietary behavior was similar to that of animals subjected to other nonspecific gastrointestinal procedures. Body weight remained at normal levels.

(*d*) *Motor Function.*—Fluoroscopic observation of the barium-filled colon and interposed segment of the ileum disclosed an interesting sequence of events (Figs. 2 and 3). As barium was introduced, the rectum filled in relatively normal fashion. Shortly thereafter a thin trickle of barium rapidly traversed the interposed ileal segment in an antiperistaltic direction, filling the proximal colon. As filling continued and the interposed ileal segment was subjected to distention, it responded by exhibiting vigorous segmenting and peristaltic movements of a type characteristic of the small intestine. It was clear from the observations that the graft, the colon proximal to the graft, and the rectum distal to the graft contracted with entirely distinct rates and rhythms. The graft therefore func-

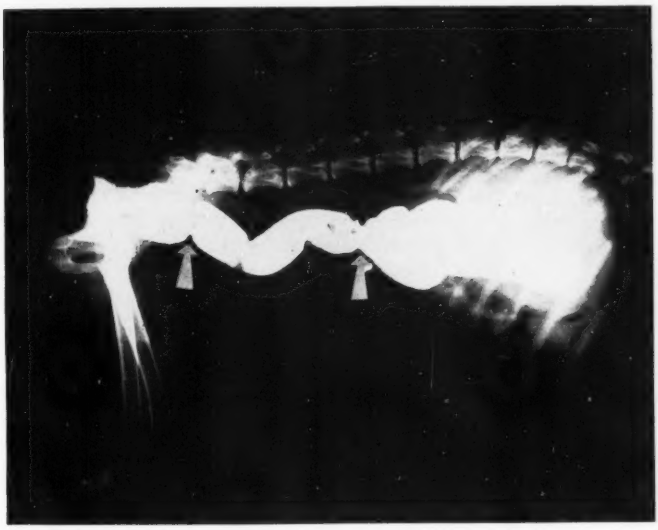

Fig. 2.—Barium-filled rectum, interposed ileal segment, and proximal colon. Arrows indicate sites of anastomosis.

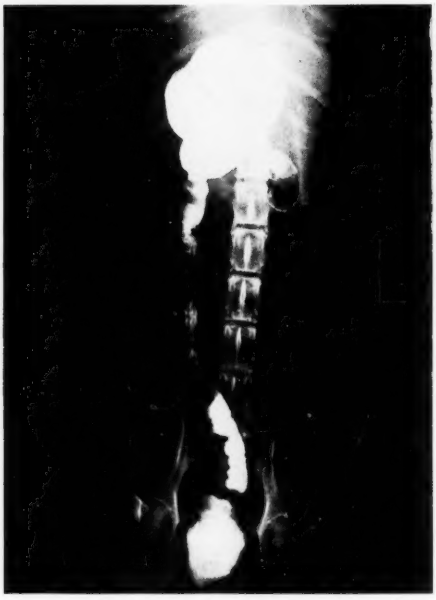

Fig. 3.—Proximal colon and rectum remain filled with barium, while ileal segment is almost empty. Intrinsic motility of ileal segment results in more rapid emptying.

tioned autonomously from the colon in which it was placed. There was no synchronization of activity of the proximal colon, the ileum, or the distal rectum. However, the indirect influence of each upon the other was evident. Typical colonic contractions of the proximal colon led to the forceful introduction of material into the ileal graft, stimulating segmenting and peristaltic waves in the transplanted segment. Peristaltic waves formed at the proximal end of the segment and effectively transported the barium into the rectal stump, which thereupon reacted in its own characteristic manner with effective expulsive contractions. Thus, although in every case it was seen that the ileal segment retained its identity as small intestine and functioned independently of the surrounding colon, the proximal colon, the interposed segment, and the residual distal colon or rectum formed an effective defecatory unit.

Analysis of the kymographic recordings of the contractile activity of the proximal colon, the ileal segment, and the residual distal colon or rectum by simultaneous pressure recordings with intraluminal balloons confirmed the observations made fluoroscopically on the barium-filled bowel (Figs. 4 and 5). Contractile waves from the colon proximal to the ileal segment were normal Type I, Type II, and Type III movements. The frequency of Type I movements was three to eight per minute, and the reinforced Type II contractions lasted approximately one minute. General tonal changes or Type III colonic waves occurred infrequently and, in general, persisted for several minutes. The rectal contractions, while not

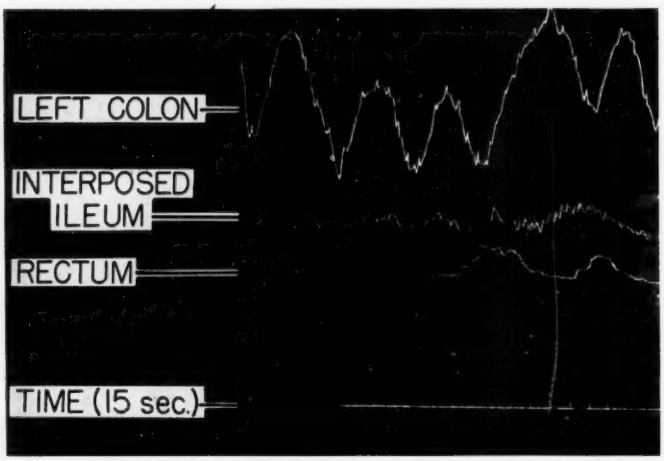

Fig. 4.—Each segment retains its own pattern of motor activity. Type I and Type II pressure increases are recorded in the colon. Normal segmenting pressure increases are recorded in the ileum.

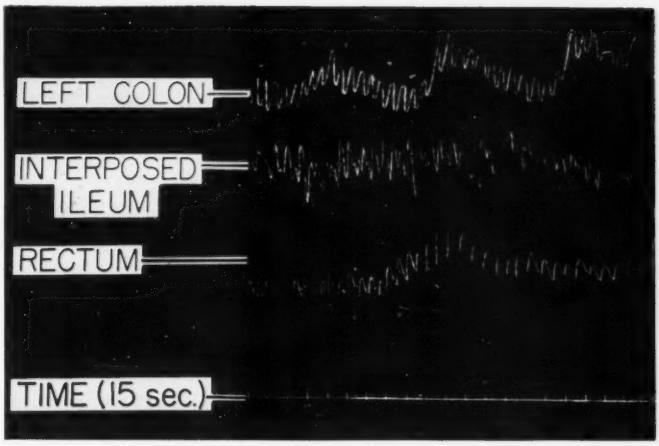

Fig. 5.—Pressure increases in left colon, ileal segment, and rectum occur independently of each other.

synchronous, were quite similar in type but of diminished amplitude in the anesthetized animal. The recorded pressure changes in the interposed ileal segment were of much smaller amplitude, and segmenting movements occurred at the rate of 12 to 25 per minute. The tonus changes were more gradual than those of the colon and were of smaller amplitude. The general increases in tone were invariably accompanied by superimposed segmenting type waves. Observation of these motor phenomena over periods of several hours clearly demonstrated that the motility characteristics of the colon and rectum had no direct influence on the pattern of motility in the graft. The transplanted segment retained its functional autonomy and characteristics of small intestine. The colon above and below the transplant retained its autonomy and distinctly different motor pattern. Although the proximal and distal colonic segments demonstrated similar motor activity, the interposition of the ileum led to a complete temporal disassociation of the contractile activity of these two colonic segments. It was only when an increase of pressure of great magnitude occurred in the proximal colon, as occurs in the course of a colonic peristaltic rush, that pressure changes were rapidly transmitted across the ileal segment and resulted in apparently synchronous behavior of the proximal and distal colonic segments.

(*e*) *Anatomic Changes.* — After several months of interposition in the left colon, the transplanted ileum demonstrated minor but consistent and recognizable anatomical alterations (Fig. 6). Most noticeable was

Fig. 6.—Ileal segment interposed four months in the left colon exhibits increase in caliber and muscular hypertrophy.

the increase in the diameter of the interposed segment. The transplanted bowel was found to have a diameter approaching that of the colon in which it was placed. The wall of the graft was consistently thickened and demonstrated hypertrophy of the muscular layers. The valvulae conniventes were still observable in the ileal segment.

Microscopic examination demonstrated an intact mucosa with normal villi. There was some increase in the number of lymphocytes present in the submucosal layer, but there was no other evidence of inflammatory alteration. At the anastomotic sites, a sharp line of demarcation existed between essentially normal ileum and essentially normal colon mucosa.

Comment

In view of what is known of the innervation and functional autonomy of the gastrointestinal tract the results are not surprising. The mortality rate from causes related to the operative procedure in the series of animals here reported is 18%. In the group in which all anastomoses were made intra-abdominally, there were no mortalities. In the series in which the distal anastomosis was performed, by the pull-through procedure, the mortality rate from causes related to the operative procedure was 33%. It is significant that the deaths occurred in the first two animals which were subjected to the procedure. As proficiency was gained and critical points in the procedure were recognized, there were no mortalities in the last animals operated upon.

The critical technical maneuver was mobilization of the vascular pedicle of the ileal graft and delivery of the distal end of the graft through the everted anus for anastomosis. The terminal ileum is usually supplied by the lowest branch of the superior mesenteric artery. Extensive mobilization of the vessels supplying the segment requires dissection to their origin at the superior mesenteric artery and must be performed with care. In all of the cases here reported, the number of vascular arcades utilized depended entirely upon the length of ileum required. Single arcades were found to offer adequate blood supply and permit easier and more extensive mobilization.

The postoperative alteration in stool consistency and frequency basically remains unexplained. It may well be that the postoperative diarrhea represents a localized enteritis in the transposed segment as a result of the fecal content, to which it is exposed for the first time. The duration and severity of the diarrhea is related inversely to the length of distal colon and rectum which remains. This would appear to result from two phenomena: (1) the ability of the rectum to reabsorb water from the feces and (2) the storage capacity of the rectum. It has been shown in humans that, even in the presence of excellent sphincter function, the frequency and urgency of defecation increases as progressive lengths of rectum are sacrificed. The return of the stools to normal consistency also remains unexplained and apparently represents much the same adaptive phenomenon as the alteration in the consistency of colostomy drainage.

The autonomy of small intestine is well known and is apparently a property of smooth muscle as well as of the intrinsic nerve plexuses. Segmenting movements of the ileum occurring at a rate of 12 to 30 per minute, with waves of peristalsis occurring much less frequently, are normal. When a segment of ileum is transplanted into the large intestine, with its blood supply intact and its extrinsic nerve supply partially so, it is not surprising that its normal motility pattern is retained.

The behavior of the colon proximal and distal to the graft is also of interest. The bowel retains its intrinsic behavior pattern, and yet there is disassociation of activity of the proximal and distal segments. This appears to be related to the division of the intrinsic nervous mechanisms as a result of the resection and, more important, the interposition of a mechanically distinct seg-

ment. Alterations in intraluminal pressure therefore are not transmitted directly from proximal to distal colon. Each segment responds normally to any stimulus, but the smooth transmission of stimuli from proximal to distal colon is interrupted. Nonetheless, the complex of proximal colon, interposed ileum, and distal colon functions as an effective expulsive unit.

The relatively minor anatomic changes observed in the transplanted segments are similar to those seen in other muscular organs subjected to altered stresses. They represent hypertrophy of the muscular layers.

There are instances of resection of the left colon in which the location of the lesion allows preservation of the anal sphincter mechanism but in which it is hazardous or impossible to bring the proximal colon to the rectal stump. The incidence of this eventuality is small and depends upon the operative procedure and the vascular configuration of the colon. In these unusual instances, interposition of an ileal segment may make it possible to preserve sphincter function without compromising the principles of cancer surgery.

Summary

Functional behavior and anatomical changes of ileal segments interposed in the left colon have been observed in the dog.

The ileal segment retains its intrinsic functional pattern but, together with the proximal and distal colon, forms an efficient expulsive unit.

In unusual instances, where sphincter preservation is possible and technical difficulty or vascular anomalies prevent adequate mobilization of the proximal colon, the use of an ileal graft may be considered.

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DISCUSSION

ON PAPERS BY DRS. COLEMAN AND ECKERT AND THOMPSON AND WATMAN

DR. RUPERT B. TURNBULL JR., Cleveland: I am sure you join with me in congratulating Dr. Coleman and Dr. Eckert on their report of a carefully followed series of patients with disseminated polyposis. Their advice is good, that is, to treat each patient with polyposis according to the circumstances. In this day of the radical sweep for everything or anything in the name of cancer, their kind consideration for preservation of the rectum is refreshing.

Practically all patients have been cooperative in returning for periodic examinations. A few years ago we traced 29 of these patients who underwent colectomy with ileorectostomy, and two findings were outstanding: Every patient with a cancer at the time of his operation later died with metastasis. This shows the absolute indication of treating these people surgically as soon as possible. All the others have survived, and none developed cancer in the rectal stump. Perhaps more time may be necessary for the final evaluation in this regard, although approximately 15 years have elapsed since the first of the patients was operated on.

A few technical considerations: End-to-end ileorectal anastomosis is hazardous. If the anastomosis is made in the lower sigmoid colon, where there is no disparity in the sizes of the two pieces of intestine, it is feasible, but in the rectum proper the operation is hazardous. A small, thin-walled ileum is connected to a large, thick-walled rec-

tum. Too much is expected of it. The disparity in size is compensated for by fitting the large viscus into the smaller one.

An alternate plan is to simply close the end of the ileum and make a side-to-end ileorectal anastomosis. This will not leave any pouch for carcinoma or polyp to hide in.

Occasionally, the decision to sacrifice a rectum is made because there are so many polyps present that normal mucosa cannot be seen. Dr. Coleman has shown us a picture of one of these. I would like to make a plea for a try at fulguration, because many of these polyps are so edematous and so much enlarged that they hide the normal rectum mucosa underneath and after a preliminary fulguration one can see his way clear to preserve the rectum.

The authors bring up the question of sexual potency following rectal mobilization. Recently I had occasion to follow 53 patients undergoing abdominal perineal resection for benign disease, that is, ulcerative colitis and polyposis, and in only one case was the patient impotent. In one other case the patient was potent but did not ejaculate, and in four others potency was assured but ejaculation was delayed for a few months, but all recovered.

DR. C. BARBER MUELLER, St. Louis: I should like to discuss the second paper, on the interposition of the ileum.

A few years ago Dr. Haffner, Dr. Eiseman, and I were interested in this problem. We operated upon a series of dogs, with results similar to those that were presented this morning. We even got around to performing such an operation in one patient, and I can say that it will work.

The patient for whom this was done was a Negro woman who had had a colostomy for 15 years because of stricture due to lymphogranuloma. She was tired of the colostomy, and said she would do anything to get rid of it. She had been in cardiac failure on two previous occasions. A pedicle flap of ileum was brought down and anastomosed to the anal mucosa; the upper end was brought out through the abdominal wall, and six weeks later it was anastomosed to the descending colon.

One of the proudest moments of her life was when she said, "I can go to a double-feature movie, and I don't have to get up once to go to the bathroom." I might add, her previous colostomy care left much to be desired.

She was seen at a follow-up visit last week. She has two stools a day, is perfectly content, and recognizes when she is going to have a bowel movement. Ileal juices which come from this segment down over the 0.5 cm. remaining anal mucosa are not much of a problem. On one or two occasions she has had a little redness, not an excoriation but a little irritation of the buttock skin around the anus. Other than that, she doesn't get into trouble if she pays attention to her buttocks and keeps them clean.

The use of a segment such as this, brought down and anastomosed to the anus, may be of value in staging a total colectomy for ulcerative colitis or other purposes, if it is desired to end up with an ileoanastomy.

My brief experience in watching and caring for patients with ileoanastomy indicates that the utilization of functional ileum, brought through the anus and anastomosed to the skin, presents many hazards to healing. The end-results of a staged procedure such as this seem to be pretty good.

Dr. Haffner has done this in one patient with excellent results. The ileal mucosa is anastomosed to the skin, and the patient has four stools a day. She is able to recognize when bowel movements are going to occur. She works as a stenographer in a large office and is able to care for herself perfectly well, with no problem of a hurry-up trip to the bathroom.

The procedure described here can be a useful procedure, and I believe it should be explored further. I think there is going to be an occasional patient who may have considerable benefit from such an approach.

DR. LOUIS T. PALUMBO, Des Moines, Iowa: I should like to compliment both speakers on their excellent presentations. I should like to restrict my remarks to the paper by Drs. Coleman and Eckert.

I agree with their indications for preservation of the rectum. However, in the last five cases during the past five years we haven't been that fortunate. The patients we have seen have been of the type with very extensive disease, involving the entire colon, including the rectum, also with cancer involving both the ascending and descending colon.

[Slide] This slide shows a close-up of the specimen, with carcinoma in the large polyp in the ascending and descending colon.

[Slide] The second case shows the rectal stalk with extensive involvement, and in this case early carcinoma was detected.

[Slide] The third case also had extensive disease, with many sessile polyps.

In four patients we did a total colectomy including abdominal-perineal resection and ileostomy all in one stage; in three of them carcinoma was found at the time of surgery. We preserved the rectum of the fifth patient and followed him carefully for a period of a year and a half. At the end of that time we detected carcinoma in the rectal stalk and had to perform an abdominal-perineal resection.

Of these five cases, then, four had carcinoma, and all of the patients died within two years following surgery because of the malignancy.

DR. JOSEPH H. HAMILTON, Louisville: I have enjoyed both of these papers very much. I should like to discuss the paper by Drs. Coleman and Eckert and to add our experience at the Louisville Veterans Hospital with eight cases of multiple polyposis of the colon, seven familial and one nonfamilial.

The first two patients with familial polyposis were therapeutic failures. One of them refused treatment altogether and drank himself to death. The other developed very malignant cancer in two of the rectal polyps despite treatment and died of his disease 16 months after a total proctectomy.

The remaining six patients have all been treated by one-stage colectomy and open end-to-end ileorectostomy. The rectal stumps of the five with familial disease, of course, were cleared of polyps by fulguration.

A Swenson type of procedure, with anastomosis 5 cm. above the anal verge, was carried out in two patients with unusually numerous polyps, some of which showed atypism. The remaining three, including the one patient with a definite napkin-ring carcinoma of the upper descending colon, were submitted to low anterior anastomosis 10 to 14 cm. above the anal verge. There have been no postoperative deaths, and all six patients have now been followed from four and a half to seven and a half years without evidence of intercurrent or recurrent carcinoma.

In the three of the five patients with the familial disease, small new lesions have continued to appear from time to time and have required fulguration for from two to seven years after the original colectomy.

This illustrates again that such patients require careful follow-up for an indefinite period. If this surveillance is maintained, sphincter preservation seems to us both safe and feasible as long as the new lesions cropping up remain innocent and controllable.

The Swenson procedure appears ideal to us when there are more polyps than usual or they are relatively more numerous or tend toward atypism.

Two of the six surviving patients developed peptic ulcers, one gastric and one duodenal, requiring surgery for massive hemorrhage three and four years after the colectomy. I do not know whether any possible relationship may exist there.

DR. CHARLES ECKERT, St. Louis: I should like to thank Dr. Turnbull, Dr. Palumbo, and the other discussers for their remarks. I believe there is no disagreement with the general thesis that individualization is required in the treatment of this disease.

To illustrate the complexity of the problem—one of the patients in our series is a boy aged 13. Two aunts have died of cancer of the large bowel. In examining the other members of his family, the father, aged 43, and one brother, aged 20, were each found to have a solitary pedunculated adenomatous polyp in the low sigmoid. X-ray studies, including barium enema, were negative. While these patients probably have familial polyposis, it is impossible to recommend treatment other than local removal. Both persons are aware of their problem and its attendant risk; I feel certain they will cooperate in securing regular examinations. I wonder if others would recommend total colectomy under these conditions?

Cancer of the Breast, 1661 Patients

I. Considerations in Future Therapy

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Mammary cancer is probably the commonest cancer seen among hospitalized women. As much or more has been written regarding breast cancer as about any other cancer, and many types of therapies have been proposed. Inasmuch as human breast cancer is a current controversial therapeutic subject, this study was undertaken to help guide our future efforts by past experience.

While the issues of superradical surgery, radical surgery, and limited surgery, with or without radiation, are contested, there lurks forever the question of how influential is therapy. We believe that the prognosis for the breast cancer patient is related to therapy, but prognosis and results are by no means dependent upon therapy alone. To aid our future patients, it appeared that data about the effectiveness of past curative attempts should be obtained. In addition, certain information might be had to suggest possible changes.

Material

This series of 1661 patients with breast carcinoma represented the recorded patient material for 24 years at the University Hospitals, State University of Iowa. In essence this was nearly a quarter century of cumulative experience, from Jan. 1, 1926, to Jan. 1, 1950. The patient material was varied, as might be expected in any large medical center depending upon physician referrals. Treated, partially treated, and untreated patients were seen at every stage compatible with the natural history of the disease. The University Hospitals serve largely the indigent ill of the state, so some selection did exist financially, but as the study included the financial depression years this lacks a reliable base. There was no specific ethnical selection other than that the state's population is predominantly Caucasian. It was impossible to interpret accurately urban and rural residence, particularly since many farm families change to an urban address upon entering the cancer age group. This inquiry was undertaken initially to differentiate factors causing delay in treatment. The University Hospitals' surgical therapy was carried out by more than 75 different surgeons, most of whom were resident surgeons. The median age and average age of the patients were in the 56th year, and the 1940 census Iowa female attrition curve at 56 years was used for comparison purposes.

Method

In review, a master sheet was prepared from which collected data * could be transferred to an I.B.M. † card. The Tumor Registry supplied material from which survival data were obtained. The Tumor Registry statistician (E.E.W.) supervised the calculations of statistical information. As the University Hospitals are a regional hospital, with the State of Iowa its community, liberal use was made to augment survival and other information of the state's Bureau of Vital Statistics, the local health and other public offices, and assistance from the referring physician. This did present difficulties, for some follow-up was indirect. Because of distances involved, routine hospital follow-up was not insisted upon uniformly; economically

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* Assistance was given by Drs. Martha C. Adrian, Zae Aschenbrenner, John Crivaro, Ralph Holloway Jr., and William Sterns, while fourth-year medical students.

† International Business Machine Corporation.

this was not feasible in a state-supported hospital where the transportation costs of the indigent are borne by and provided by the state.

In a retrograde statistical review of this type certain other deficiencies were present. For example, what of the patient originally? What was his or her ability as an individual to communicate life experiences? What was the ability of the medical historian to elicit the history, then to record it, and at times to interpret it? All interpretations were made in the light of these weaknesses. The knowledge of ultimate patient outcome was concrete. The follow-up loss was about 3%, and these patients were considered dead as of the date lost.

In calculation of results, the data are presented both as arithmetical survivals at a standard interval and, in the manner of Berkson and Gage,[1] the calculation of an attrition curve. No attempt was made to segregate male patients (about 1%). No histological grading or tissue review of the carcinomas was attempted. All survival statistics were calculated from the date of diagnosis. The date of diagnosis was defined as the date when first administrative or therapeutic action was taken to treat the patient for cancer. The patients were treated as individual patients, not individual cancers; as, for example, a second breast involved with cancer was considered as part of the disease.

Our interests for the purpose of this paper were to determine survival results, to inquire into the effects of roentgen therapy as a supplemental primary treatment, and to learn the distribution of first cancer recurrences. The treatment of choice for primary operable breast cancer was radical mastectomy. The interpretation of data on supplemental roentgen therapy must be weighed in the light of a probable clinical selection of patients for this treatment.

Results

Survival for the University of Iowa patients, regardless of age, sex, therapy, or complete lack of therapy, and without regard for state of disease or natural attrition from other causes was 36.8% at five years from date of diagnosis, regardless of where that diagnosis was made. With respect to the future, it seems that this figure can be improved principally by lay cancer education to emphasize earlier diagnosis, thus bringing about more effective treatment. This supposition finds support in that the vast majority of breast cancers are patient-discovered, after which there is an inordinate delay to diagnosis, and further delay to treatment. The median delay from symptom to treatment (any type) was seven months. It was over two years in 18% of the patients.

The five-year survival after radical mastectomy (913 patients) was 46.8%. The 913 patients included those patients with partial mastectomy and later completion of radical mastectomy, operation with supplemental roentgen therapy, and other combinations. If the axillary nodes were free of cancer, there was a 68.7% five-year survival; with axillary node involvement, 33.1%. Distant metastases, when detected during the hospitalization of the operation, reflected poor results with but 8% of the patients surviving at five years. The actuarial curves, calculated in the manner of Berkson and Gage, are shown in Figure 1.

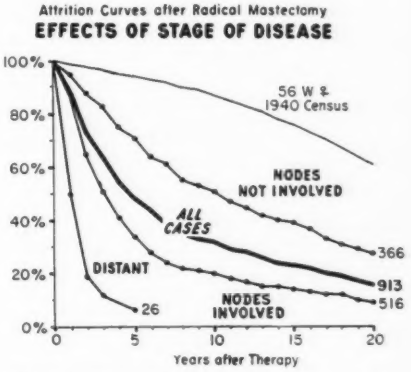

Fig. 1.—The attrition curves were calculated in the manner of Berkson and Gage.[1] "Early" cases present significantly better results.

The elective standard therapy for breast cancer was radical mastectomy. If roentgen therapy was used, was it of additional aid?

Two groups of primary operable patients were selected who had had all treatment at the University Hospitals. All had had radical mastectomy but differed in that supplemental roentgen therapy had been administered to some under the direction of one of us (H.D.K.). The supplemental roentgen treatment was used mainly between 1930 and 1940. Most patients were treated postoperatively, some preoperatively and

postoperatively, and others preoperatively only.

The technique was in general that of 200 kv. radiation, with filtration of 0.5 mm. Cu and 1.0 mm. Al (H.V.L., 0.95 mm. Cu); 200 r was administered daily to one or more various-sized fields for a total (air) dose of 2000 r to each field. The preoperative treatment included tangential fields directed into the breast. The supraclavicular area and axilla were always treated, and the operative site was treated most frequently through a 20×20 cm. portal, with a beam of 120 kv. and 1 mm. Al filtration (H.V.L., 5 mm. Al). The medial anatomic limits of this field covered the ipsilateral sternal margin.

Initially it had been planned to treat all patients with supplemental roentgen therapy over a given time span, but for various reasons this plan failed in completeness. In retrospect, it appears that a clinical selection by surgeons took place with more of the unfavorable patients falling in the radiated group. Radiation comparisons deal, therefore, only with groups numerically identified as to size and delineated by the presence or absence of metastatic cancer in axillary nodes. These latter descriptive terms, with or without involved nodes, are relative, for such a grouping is influenced by the intensity and breadth of the pathological examination. Metatastic cancer in nodes carries, however, a definite biological implication, and patients may be significantly categorized even if such is not completely accurate. When so examined (Table), little differences are noted between the patients with or without supplemental radiation. The numbers of patients considered in each group are shown in parentheses. The five-year survival difference between 70.7% and 62.3% in those without axillary node involvement is of questionable significance because of the relatively small number (77) in the supplemental roentgen therapy group. Supplemental roentgen therapy offered no survival improvement over the radical mastectomy where the axillary nodes contained metastases.

Five-Year Survival, After Radical Mastectomy With and Without Supplemental Roentgen Therapy

	With Axillary Node Metastases*		Without Axillary Node Metastases*	
Radical mastectomy	31.5%	(216)	70.7%	(215)
Radical mastectomy with roentgen therapy	29.8%	(182)	62.3%	(77)

* Figures in parentheses indicate number of patients considered in each group.

The appearance of the first recurrence after breast cancer therapy heralds the failure to cure. Figures 2 and 3 demonstrate the pattern of recurrent disease at the first clinical sites after radical mastectomy and after radical mastectomy with supplemental roentgen therapy. Again, the patients were grouped by the presence or absence of metastatic axillary node involvement. Where the histological examination of the axillary nodes showed freedom of secondary deposits, the recurrence rate tended to be delayed by comparison and to be strikingly less frequent. At times more than a single site was included as first, and accordingly on the bar graphs the total patients considered are indicated immediately subjacent to the corresponding time interval.

These figures might be prejudiced toward incompleteness, but they do present a significant trend. The local area and axilla

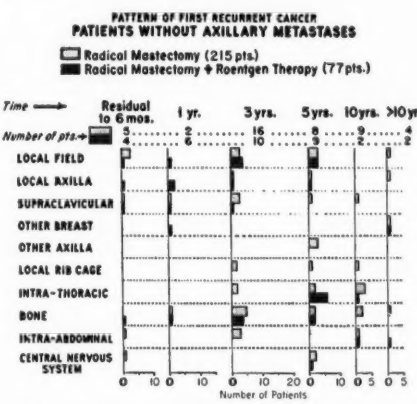

Fig. 2.—The presence or absence of axillary nodes is reflected in the recurrence rate and pattern, as noted by comparing Figure 2 and Figure 3.

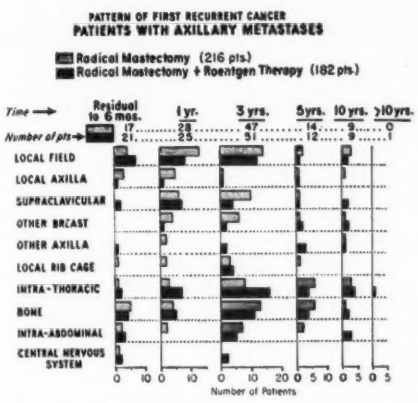

Fig. 3.—The high rate of local and regional recurrences was discouraging, for this is the area presumably cleared by any therapeutic mastectomy.

tended to have a high recurrence rate. The local area was of particular importance, for this was presumably the area cleared surgically by the classical radical mastectomy. In general, as shown, the time of local recurrence tended to appear soon after operation. An element of discouragement is present when one notes in the time relationship that even after 10 years the first recurrence may be local. We would disallow that this represents poor surgery entirely but rather reflects the disease, breast cancer. Also, even with the patients in whom the cancer was thought to be limited to the breast, there was no assurance against early distant spread.

These do not represent total recurrences, as, for example, McDonald, Haagensen, and Stout [2] cite 21.8% supraclavicular recurrences in patients treated from 1915-1934 at the Presbyterian Hospital, New York City. Urban [3] states that 10% of 350 patients treated for medial quadrant lesions had recurrences in the parasternal region. The early appearance of involved supraclavicular nodes is a well-known clinical observation and is herewith substantiated, as seen in both Figures 2 and 3.

No appreciable change was shown in the general scattered and proportionate pattern of recurrences when roentgen therapy was added to the radical mastectomy as a therapeutic endeavor. Collins [4] states that one of the benefits of postoperative irradiation may be to reduce the rate whereby locally recurrent disease appears over the axilla and the mastectomy site. With the technique used upon this series of patients, the radiation did not alter the first recurrence pattern.

Comment

The radical mastectomy operation, identified with the names of Halsted [5] and Willy Meyer,[6] was developed independently by each just before the turn of the 20th century. Radical mastectomy was recognized then, as now, to have limitations. Quite soon after the operation was reasonably standardized, efforts were made to improve the results. The logical turns were to extended surgery and to radiation therapy, the latter either alone or supplemental, as radium or roentgen therapy. These controversies are with us still.

Judicious and skillful x-ray therapy is one of the most versatile and effective palliative agents for use in breast cancer, either at the primary site or at localized metastatic deposits. Our data are not similar and thus available for comparison to those of McWhirter,[7] who would use simple mastectomy and postoperative x-ray therapy. McWhirter's work represents an interesting clinical trial, but we would tend to agree as of now with Ackerman.[8] Upon review of McWhirter's records, Ackerman suggested that the standard radical mastectomy should not be forsaken, that this operation offers the patient the better chance for long-time survival.

With respect to radiation therapy as a supplement to the classical radical mastectomy, our data offer no encouragement. A controlled experimental comparison is not, however, presented.

McDonald, Haagensen, and Stout [2] have stressed quite logically that the patients be selected, that the therapy be fitted to the patient; with rigid selection of patients to be operated upon, the results for the radical

mastectomy operation will be improved statistically.

The early efforts to extend the radical mastectomy were by Halsted.[9] He commented upon three mediastinal dissections performed by Dr. Harvey Cushing, and in 1898 he had carried out supraclavicular dissection as a portion of the initial therapeutic endeavor. Handley[10] directed his attention to the internal mammary chain of nodes, with use of radium implantation. More recently, numerous surgeons have proposed various extensions with varying techniques. Only three representative groups will be commented upon.

Wangensteen[11] and Lewis[12] describe a vigorous surgical attack on advanced breast carcinoma, carrying out a mediastinal dissection, supraclavicular dissection, simple amputation of the clinically uninvolved contralateral breast, and a radical mastectomy. The operative specimens have shown in 60% of the patients an extension beyond the axilla by carcinoma. The hospital mortality rate has been 12.7%. From the known natural history of the disease, it is postulated that any possible improved results will be less than the hospital mortality rate and that the procedure will be abandoned in its current conception.

Urban and Baker[3] have described an earnest clinical trial of extended radical mastectomy carrying out an en bloc dissection of the internal mammary lymph chain. This extension of radical mastectomy focuses attention surgically upon an additional avenue of spread, and the supraclavicular area is treated by roentgen therapy. With a low complication rate the procedure may have merit if early cases are selected.

Margottini,[13] in Rome, is the earliest current-time advocate of extended radical mastectomy and has had the most extensive experience. His operation is not aimed at increasing the criteria of operability. Margottini now performs an en bloc radical mastectomy and internal mammary node dissection and a staged supraclavicular dissection. At the Sixth International Cancer Congress, in 1954,[14] he reported upon 492 radical mastectomies with excision of the internal mammary chain and 157 supraclavicular prophylactic dissections. Recently‡ he has been able to compare, for the years 1948-1950, a total of 150 cases of an extended operation with 150 cases of the classical radical mastectomy; he noted a 15% increase in five-year survival. This is encouraging.

It is, of course, clinical experiments of the types described which may alter our future concepts of breast cancer therapy. The observation periods have been too scant thus far for conclusions. It may well be that for medial or inferior breast cancers the internal mammary dissection will become most useful. In hospitals or clinics where superradical surgery is done, there must be an over-all improvement in all operable breast cancer results with other variables constant. Otherwise the improved results attributed to superradical surgery will but reflect clinical and biological selection of patients and cancers treated by the extended surgical procedures.

In the considerations of future therapy, the classical radical mastectomy should not be abandoned as yet. Realistic patient selection should determine those patients subjected to operation. Simple mastectomy and/or roentgen therapy should be used for palliation. The high rate of locally recurrent disease as the first manifestation of failure in our patients is discouraging, for this is the area presumably cleared by the standard operation and, by analogy, any other therapeutic mastectomy. This may be due in part to surgical technique. Certainly more careful dissection and more rigid guarding against implantation should lower this incidence. Upon consideration of the extended or superradical surgery, a realistic view of the natural life history of the disease must be held. For the late cases, such an operation is futile. Those surgeons who would undertake an extended operative program should do so with serious intent and not

‡ Margottini, M.: Personal communication to the authors, Jan. 30, 1956.

upon a few chance patients from whom no conclusions may be drawn. Public education, to aid early diagnosis, thus bringing more patients to the surgeon promptly, must be encouraged as a potent force for better results.

Summary

A cumulative experience of 24 years upon 1661 patients is reviewed.

At five years from diagnosis, the over-all survival among 1661 patients is 36.8%.

The five-year survival rate upon all patients treated by radical mastectomy is 46.8%.

A group of patients treated by radical mastectomy had supplemental roentgen therapy. The roentgen therapy offered no measurable benefit in terms of survival and pattern of first recurrence. In general, these cases were clinically more unfavorable.

The local recurrence of cancer as the first manifestation of failure to cure was discouraging. The first appearance of a distant metastasis was unpredictable. These data and the survival curves reflect the biological history of breast cancer.

For most surgeons, the classical radical mastectomy should not be abandoned as yet. Techniques should be improved, and patients to be treated by radical mastectomy should be selected more carefully. Superradical surgery should be considered as a clinical experiment for observation.

Public education with early diagnosis and prompt treatment should be encouraged to improve realistically the over-all results.

DISCUSSION

DR. DONALD M. GLOVER, Cleveland: The authors have presented an excellent review of the course of breast cancer in a large teaching hospital over a quarter of a century, as influenced in a general way by the stage of the disease and the type of therapy employed. With most of their conclusions I am in complete agreement. I am not certain, however, that their statistics provide adequate sampling to conclude that postoperative irradiation has no significant influence upon survival rates. It is difficult to obtain conclusive figures upon this controversial point. We have seen impressive evidence that breast cancer cells may be present and remain encapsulated by the irradiation reaction for from 1 to 20 years. The best figures available will show perhaps 5% more survivals in patients with axillary metastates who have been irradiated following radical mastectomy than those who have not. This may not seem a very significant salvage rate, but to the patient who represents one of those percentage points and whose life is prolonged for several years, it may be worth a great deal.

From what information is presently available, ultraradical surgery does not seem to be justified for the average surgeon. Two years ago we presented before the Association a preliminary study on the use of a simple type of internal mammary lymph node dissection as something of a prognostic guide in medial quadrant neoplasms. We have continued the study and still believe that employment of the procedure as part of an en bloc resection is not justified at present. It is certainly justified, however, for certain clinics to carry out these ultraradical procedures in an effort to evaluate their effectiveness.

I find it very difficult to attempt to compare figures on treatment of carcinoma which contain many hidden variables, as most of our cancer statistics do. Perhaps no two of us in this room would agree upon exactly what constitutes a proper radical mastectomy, and perhaps no one of us would perform an identical operation upon successive days; nor would we agree upon what constitutes adequate postoperative irradiation. But we have no exact information upon what influence these apparently minor variations have upon survival rates. Other items we must know about if we are to compare statistics are the criteria for inoperability which were observed during the study and the fidelity with which the pathologist searched for involved lymph nodes and recorded them numerically. It is hardly necessary to call attention to the effect upon statistics which may be produced by (1) the failure of the pathologist to find in the specimen involved lymph nodes which are there, or (2) ineptitude upon the part of the surgeon who leaves nodes containing tumor in the patient.

There are still so many unknowns in the behavior of malignant tumors that we are working partly in the dark. We need cold, objective evidence such as might be provided by the careful documentation of personal lifetime experience of many surgeons, such as those who comprise this Association.

DR. ROBERT C. HICKEY, Iowa City: We presented here the entire, total experience of all patients who were seen, treated or untreated, and with various types of treatment, whether it had been or had not been given initially at the University Hospitals.

With respect to criteria of inoperability, it can be seen that there were 26 patients with advanced disease upon whom primary radical mastectomy was carried out; these either had at operation evidence of distant spread, or metastases were found prior to the time they left the hospital. So, actually, the criteria of operability were rather liberal.

With respect to nodal involvement, the groups that received supplemental irradiation had proportionately more patients demonstrating metastatic deposit in the axillary nodes. With the groups so divided and then matched, those with against those without roentgen therapy, there was no appreciable change in the attrition curves. To continue to subdivide could potentially confuse, and this was not done. It remains that supplemental irradiation therapy afforded no additional benefit to our patients treated by radical mastectomy with the techniques used.

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Results of Pelvic Exenteration

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The operation of exenteration of all pelvic viscera with urinary and fecal diversion has been under critical evaluation for the past several years. Since July, 1947, a total of 118 such operations have been performed by us in St. Louis for various lesions (Table 1). Previous publications * have included patients operated upon at the Ellis Fischel State Cancer Hospital at Columbia, Mo., by Dr. John Modlin and Dr. Henry Schwarz. This study does not include these patients. Following the lead of Brunschwig and others,† advanced carcinoma of the cervix and other lesions of the female genital tract were added to the study in April, 1950. It is the purpose of this report to add our own current evaluation of this procedure to those appearing in the literature in recent years.‡

The operation has been described previously § and is performed in the same manner at the present time. The essential features include en bloc resection of all pelvic viscera with an associated pelvic lymphadenectomy and resection of the perineum. There have been a few deviations from the standard procedure. The levator sling and a stump of rectum were preserved in three instances for restoration of rectal function. Resection of the common and external iliac veins along the internal iliac vein, which is routinely removed, was done seven times. The iliac artery was excised twice and replaced by an autologous arterial graft of the ipsilateral superficial femoral artery. These variations for the most part represent extensions of the operation and are included with all others in this analysis. Two or three limited exenterations (anterior or posterior) have been performed during this period but are not included in this study.

Although it was not unusual for operations to require six to eight hours for completion at the beginning of this experience, it is unusual if one requires over four hours now. The requirements for blood replacement have also diminished, five or six units being adequate for the operation and the immediate recovery period in the average case at the present time. However, it is still wise to have facilities available that can

TABLE 1.—*Pelvic Exenteration—Total Experience July, 1947, to February, 1956*
118 Operations

Type of Lesion		No.
Carcinoma		
Cervix		86
Squamous cell	76	
Adenocarcinoma	10	
Rectum		12
Endometrium		6
Vagina		2
Anus		1
Bartholin gland		1
Ovary		1
Bladder		1
Sarcoma		
Prostate		1
Uterus		2
Melanoma		
Vagina		1
Radionecrosis		4
Total		118

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The members of the Department of Obstetrics and Gynecology of Washington University School of Medicine cooperated in this clinical study.

* References 3 and 5.
† References 7, 8, 9, and 12.
‡ References 10, 11, and 13.
§ References 3 and 6.

double or triple this supply of blood if necessary. The average period of hospitalization of the 102 survivors after operation was 30 days. It is seldom now that a patient requires 21 days of postoperative hospitalization before discharge.

In all but two of the patients in this study[2] the method of substituting for the urinary bladder has been by transplanting both ureters to an isolated segment of terminal ileum which drains the urine through the right lower quadrant of the adbominal wall into a glued-on bag.‖

Operative Mortality

Table 2 lists the causes of operative mortality. Included as operative deaths are all patients dying before discharge from the hospital following exenteration. The over-all mortality has been 15 deaths in the series of 118 operations (13.5%). There have been 12 operative deaths in the 86 exenterations for carcinoma of the cervix (14%). It is of interest that the over-all mortality prior to February, 1953, was 11 deaths out of 57 operations (19.3%). In the succeeding three years, this figure has dropped to 5 in 61 operations (8.2%).

TABLE 2.—*Operative Mortality (Hospital Mortality)*

	Operations	Operative Deaths	Mortality, %
Carcinoma of cervix	86	12	14
All other lesions	32	4	12.5
Total	118	16	13.5
Mortality since February, 1953	61	5	8.2

Five of the operative deaths are directly attributable to the bladder substitution procedure (Table 3). The patient dying of pyelonephritis had severe pyelonephritis and hydronephrosis prior to operation. The group of four patients listed as dying of pulmonary embolus had other complications

‖ References 4 and 5.

TABLE 3.—*Causes of Operative Mortality*

Hemorrhage	3
Pulmonary embolus	4
Bilateral ureteral obstruction*	1
Intestinal obstruction	2
Necrosis ileal segment*	1
Pyelonephritis*	1
Cardiac failure	1
Convulsions	1
Small bowel fistula*	1
Retraction ileal segment*	1
Total	16

* Referable to bladder substitution.

that undoubtedly contributed to death, but in the absence of a more definite terminal cause, they are so listed. A total of five patients have had convulsions, probably from some unrecognized electrolyte imbalance. The patient listed as dying of this abnormality had no other identifiable cause for death.

Early Complications

Table 4 lists the early fatal and nonfatal complications and those requiring reoperation in the early postoperative period. Fifty-

TABLE 4.—*Early Postoperative Complications*
34 of 118 Patients Had Early Complications
55 Complications in the 34 Patients

Complications	No.	Reoperated	Fatal
Intestinal obstruction	15	4	2
Hemorrhage	5	2	3
Wound infection	9		
Convulsions	5		1
Thrombophlebitis	3		
Retraction colostomy stoma	1	1	
Cardiac failure	1		1
Septicemia	1		
Postoperative psychosis	2		
Pulmonary embolus	4		4
Peritonitis	1		
Retraction ileal stoma*	4	3	1
Urinary-fecal fistula*	1	1	1
Necrosis ileal segment*	1	1	1
Anuria* (ureteral obstr.)	1	1	1
Pyelonephritis*	1		1
Total	55	13	16

* Attributable to bladder substitution.

five complications occurring in 34 of 118 (29%) patients is a high incidence, but hardly surprising in view of the magnitude and complexity of the operation. Of the 118 patients, 11% were subjected to reoperation for postoperative complications. Since death from hemorrhage has disappeared as a complication with increasing experience, attention might be focused on the high incidence of postoperative intestinal obstruction with two resulting deaths, and on the four deaths from pulmonary embolus. As indicated above, most, if not all, of the pulmonary emboli were due to prolonged morbidity resulting from other lesser complications. It is of interest to note the relatively small number of complications referable to the bladder substitution procedure (6.8%, with 4.2% of them fatal).

Late Complications

The complications occurring after discharge from the hospital following exenteration are listed in Table 5. Those directly attributable to recurrent carcinoma for which no further therapy was possible are not included. These late complications group themselves roughly into four categories: (1) those referable to the external stomata; (2) those secondary to healing of the large pelvic defect; (3) recurrent cancer, producing symptoms demanding surgical intervention, and (4) complications referable to the urinary tract. It will be noted in Table 5 that any condition requiring surgery subsequent to the exenteration is listed as a complication. This factor seems to be of great importance in evaluating a procedure that

TABLE 5.—*Late Complications*
31 Patients out of 102 Survivors of Operation Had Late Complications
48 Complications in 31 Patients

Complications Requiring Subsequent Surgery			
Complication	**Operation**	**No.**	**Fatal**
Stenosis ileal stoma*	Revision stoma	5	
Perineal sinus	Excision sinus	5	
Hydronephrosis*	Revise ileal bladder	3	1
Stenosis colostomy	Revision colostomy	4	
Ventral hernia	Repair hernia	1	
Intestinal obstruction	Laparotomy	4	1
Pain (recurrence)	Cordotomy	2	
Fecal fistula	Resection bowe	2	2
Hemoptysis (metastasis)	Thoracotomy	1	
Pulmonary metastasis	Pneumonectomy	1	
Recurrent carcinoma of colostomy stoma	Resection stoma	1	
Perineal hernia	Fascia graft	1	
Pyelonephritis*	Nephrectomy	1	1
	Total	31	5

Complications Not Requiring Subsequent Surgery	
Complication	**No.**
Hydronephrosis*	4
Renal calculi*	3
Pyelonephritis* (Mild, 6; Severe, 4)	10
Total	17

* Attributable to bladder substitution.

is predominantly of only palliative benefit. The fact that 31 of 102 patients surviving the operation required subsequent surgery deserves careful appraisal.

Late complications referable to the external stomata were uniformly those of stenosis and were of minor consequence. Most were corrected by minor operations under local anesthesia.

Persistent perineal sinuses resulting from malhealing of the pelvic defect can be troublesome, and operative correction can be formidable. The lower end of the abdominal wound may be involved. The fact that five such sinuses were corrected surgically without mortality is a most fortunate occurrence. Only one patient has had a perineal hernia to such an extent and with such symptoms that surgical correction was warranted. Most of the instances of late intestinal obstruction can also be attributed to healing and obliteration of the pelvic defect since the point of obstruction is usually deep in the pelvis.

Recurrent or metastatic carcinoma accounts for approximately one-third of the secondary operative procedure. The pneumonectomy and thoracotomy for metastases were in retrospect poorly advised. Neither patient was benefited. One deep pelvic intestinal obstruction was due to recurrence. Pain from pelvic recurrence was relieved by cordotomy in two instances. The development of a fecal fistula through the perineum is almost certain evidence of recurrent carcinoma.

Complications referable to the urinary tract are perhaps of the greatest importance, since they may result fatally after the malignancy has been controlled. Preliminary surveys of the results of substitution for the urinary bladder by the use of isolated ileal segments have already been published.¶ Space does not permit a detailed discussion of this subject here. Suffice it to point out that in this group of patients (which is limited to patients having had pelvic exenteration) the incidence of severe urinary complications is low enough that it has not been a problem factor in their management. Only two patients (2%) have succumbed to urinary complications in the late postoperative period. One of these with bilateral hydronephrosis did not survive revision of the ureterointestinal anastomosis. The second died of sepsis in the remaining kidney after left nephrectomy for intractable pyelonephritis. Hydronephrosis and pyelonephritis have been infrequent. Seven patients have had Grade II or more hydronephrosis, three of these having been subjected to reoperation, with one death. In addition to the patient listed as dying of pyelonephritis, 10 others are considered to have had urinary infections that warrant classification as a complication (10% of 102 survivors of the operation). A more detailed study of the complications of bladder substitution by ileal segments has been published,[5] and further studies will be the subject of a future report.

Carcinoma of the Cervix

Eighty-six patients comprise the group subjected to exenteration for carcinoma of the cervix. Included with this group are 10 adenocarcinomas of the cervix. Care was exercised to eliminate all endometrial carcinomas. Four patients with a diagnosis of squamous-cell carcinoma of the cervix but from whom surgical specimens revealed only radionecrosis with no demonstrable residual carcinoma have been eliminated. Inclusion of these cases of radionecrosis and the six endometrial carcinomas would have appreciably improved the survival figures.

The 86 patients represent approximately one-third of the number of patients seen in consultation by us for consideration of exenteration. Approximately half of those accepted for the operation and subjected to laparotomy have the operation completed. Refusal to advise the operation results from consideration of several factors, the most important of which is extent of disease, local and distant, making the chance for

¶ References 4 and 5.

benefit from the procedure remote. Decision against exenteration at the time of laparotomy is based on the demonstration of metastases above the pelvic brim or extent of disease within the pelvis that makes total extirpation impossible.

Postirradiation recurrence or postsurgical-postirradiation recurrence was the indication for the procedure for 77 of the patients. Only nine patients were subjected to exenteration as primary therapy because of extent of disease or present or impending fistulae. Because of the insignificant number, these patients are included with the patients with recurrent carcinoma in this study.

Table 6 indicates the survival results in the 86 cervix carcinoma patients. The three patients dead of cause other than recurrence include the two late renal deaths and one death from undetermined cause. It is worthy of note that only one patient thus far has died of recurrent cancer after the three-year postoperative period. As pointed out by Parsons and Taymor,[13] the mortality from recurrence drops off sharply after the second year and adds significance to the results of a preliminary survey of survival after that period of time.

Thirty-eight patients were operated upon over three years ago (Table 7). The operative mortality in this early group was 21%. (The over-all mortality during the same period was a comparable 19.3% as compared with 8.2% in the prior three years.) Of the survivors of the operation, 53% have been found to be dead of recurrence by the end of the third year. In this same period of time 70% of the survivors of the operation are either dead of recurrent disease or

TABLE 6.—*Surgical Results—Exenteration for Carcinoma of Cervix*

Total Operations	Operative Deaths	Dead from Recurrent Disease	Dead from Other Causes	Alive With Disease	Alive Without Disease
86	12	29	3	6	36
Total Dead of Recurrence	Time of Death				
	1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr.
29	18	7	3	1	
Total Alive and Well	Survival Time to Present				
	1st Yr.	2nd Yr.	3rd Yr.	4th Yr.	5th Yr. Plus
36	16	6	5	5	6

TABLE 7.—*Patients Operated on Three Years or More Previously for Carcinoma of the Cervix*

Total patients operated on		38
Operative deaths (21%)	8	
Total patients surviving operation		30
Dead of recurrence (53% of 30)	16	
Dead of other causes (2 renal deaths)	3	
Alive with recurrence	2	
Alive and well (23% of 38) (30% of 30)	9	

complications of the operation or are found to have recurrent disease which will soon be fatal. To counterbalance this rather depressing figure is the fact that 30% of the survivors of the operation and 23% of all operated upon are well and without evidence of disease with a good chance of surviving five years. It is again pointed out that these patients were postirradiation-postsurgical failures or had such extensive disease that they were refused by the radiotherapist. All

nine are now leading full active lives. One, a five-year survivor, has had four or five mild attacks of pyelonephritis, not repeated for two years. A third patient required reoperation for a perineal sinus and is now well at five years. A fourth patient with far-advanced carcinoma at the time of operation has subsequently lost the function of one kidney but is clinically well, active, and without evidence of disease at three and a half years. The remainder have had uneventful postoperative courses.

In judging the palliative effect of the operation, we have selected one year as being the limit within which no palliative benefit can be considered to have resulted. In this group of 86 patients, 30 (35%) were dead within the first year (including operative deaths). In almost every instance, it is possible to attribute a postoperative death in the first year to poor judgment in the selection of patients for operation. With further experience in the selection of lesions for the operation, this figure, which we refer to as our "aggravation rate," should drop steadily. Sixty-five per cent of the patients survived a year or longer and are considered satisfactory. In these 56 patients, we feel confident that no gross error in judgment was made, and in each instance there was always the chance that a much longer survival than the one year might result.

The problem presented in the selection of patients for the operation is concerned almost entirely with the evidence of local extent of disease on physical examination. Of course, the patient must be an acceptable operative risk, of an acceptatble age, and show no evidence of remote metastases. Upon reviewing the records of the 30 patients surviving operation three or more years ago, it is found that the majority of those dying of recurrence had advanced fixation to one or both sides of the pelvis. However, four of the nine patients alive and well at the present time had advanced fixation. For this reason, it has been difficult for us to refuse operation on the finding of fixation alone. So often the fixation can be attributed equally to inflammation from associated ulceration or to radiation fibrosis. Leg pain of sciatic distribution is similarly an unreliable sign. Leg swelling, however, has been a reliable indication of inoperability. Several patients with leg swelling have been explored, and only one has been suitable for resection. This patient had a history of previous thrombophlebitis. Advanced fixation plus severe leg pain on the involved side becomes a very strong indication of possible inoperability. Leg swelling without a previous history of thrombophlebitis and the presence of lateral fixation and leg pain are in our opinion a positive indication of inoperability.

Associated hydronephrosis, which is an indication of lateral spread, appears to be significant in this small series. Of the 16 patients operated three or more years ago and subsequently dying of recurrent disease, 6 had normal pyelograms preoperatively and 10 had unilateral or bilateral hydronephrosis. Of the nine living and well, seven had normal pyelograms before operation and only two had any degree of hydronephrosis. Although it is logical to assume that hydronephrosis affects the prognosis, it is our feeling that it is of no significance alone in the selection of patients for operation.

Study of the pathological specimens reveals that carcinomatous invasion of contiguous viscera shows no correlation with survival. Of the 16 patients succumbing to recurrent disease, 10 had involvement of contiguous viscera and 6 had none. Of the nine alive and well, six specimens showed invasion of adjacent organs and three showed none. On the other hand, involvement of regional lymph nodes appears to be of definite prognostic significance. Taking the demonstration of a single lymph node metastasis in the operative specimen as an indication of lymph node involvement, it is found that of the 16 dead of recurrence, 7 specimens revealed lymph node metastases and 9 did not, while the specimens of the 9 survivors show lymph node involvement

in only 1 and none in 8. There is no doubt that the lesion that tends to remain localized and spread only by direct extension will represent the most favorable prognosis. From a practical standpoint, however, this knowledge is of little help in the selection of the patient for operation, except that the demonstration at operation of lymphatic permeation or metastasis above the pelvic brim we consider to be a positive indication of inoperability.

Lesions Other Than Carcinoma of the Cervix

Thirty-two pelvic exenterations have been done for lesions other than carcinoma of the cervix (Tables 1 and 8). Of these lesions, those most frequently requiring the procedure are carcinoma of the rectum, carcinoma of the endometrium, and radionecrosis.

Carcinoma of the Rectum.—Twelve patients with carcinoma of the rectum have undergone pelvic exenteration because of local extent of the disease. There were two operative deaths. Four of the twelve patients were females with the following indications for the radical operation: (1) massive tumor filling the pelvis and attached to the uterus and bladder (a patient, 72 years of age at time of operation, now a four-year survivor without evidence of disease); (2) recurrence in vagina and urethra following abdominoperineal resection (survived three years and died of carcinoma of the breast); (3) metastasis from rectosigmoid carcinoma to the vaginal wall at introitus (operation in May, 1955, the patient is well at the present time); (4) a large tumor with rectovaginal fistula (died of local recurrence and metastases 18 months later). The eight males in this group all had involvement of the lower genitourinary tract making the operation necessary for adequate removal. The two operative deaths in the rectal cancer group occurred in males in whom the need for exenteration was not anticipated, and the procedure was done on the spur of the moment without adequate preparation. Of the six male survivors, one died of coronary occlusion 4 years postoperatively without evidence of recurrence, another died in the first year of massive liver metastases, and the four remaining are alive and well at postoperative intervals of 2 years, 18 months, 8 months, and 4 months.

TABLE 8.—*Lesions Other Than Carcinoma of Cervix*

Lesion	No.	Operative Death	Dead of Recurrence		Dead of Other Causes		Alive Without Disease	
			No.	Survival, Yr.	No.	Survival, Yr.	No.	Survival, Yr.
Carcinoma of rectum	12	2	2	0.5; 1	2	4; 3	6	4; 2; 1.5; 1; 1; 1
Carcinoma of uterus	6	1	2	2.5; 5			3	5; 5; 4
Radionecrosis	4				1	0.5	3	4; 1; 1
Sarcoma	3	1	2	0.5; 1				
Carcinoma of vagina	2		2	1.5; 1.5				
Carcinoma of ovary	1						1	4.5
Melanoma (vagina)	1				1	4		
Carcinoma of Bartholin's gland	1		1	1.5				
Carcinoma of anus	1		1	1.5				
Carcinoma of bladder	1		1	1.5				

Our experiences with carcinoma of the rectum requiring exenteration have not been so great as anticipated at the onset of this study several years ago. The problem presented by this lesion is one of judgment in determining just when the extended operation is indicated. It is perhaps preferable at this time to err on the side of conservatism. Two comments concerning exenteration for carcinoma of the rectum might be made: 1. If one unexpectedly encounters a lesion requiring exenteration for complete removal, it would be better to stage the procedure rather than to proceed without adequate preparation. In this regard, it might be stated that the arrangement of the operative schedule to provide adequate time and assistance is important as well as the psychological preparation of the patient and his family. 2. In the final interpretation of the extent of a lesion, it is often of great help to supplement information from previous cystoscopic studies by opening the urinary bladder for direct visualization and palpation. From this small group of patients and from the experiences of others,[1] it appears that this extended operation has definite merit in selected cases.

Carcinoma of Endometrium.—Six patients with endometrial carcinoma have been subjected to exenteration. Five of this group had been treated by irradiation and surgery, while one had been treated by irradiation alone. There was one operative death resulting from bilateral ureteral obstruction. Two patients have succumbed to recurrence and metastases at two and a half years and five years. Three patients are alive without evidence of disease at five, five, and four years. No conclusions can be drawn from this small group. However, the results seem quite gratifying in spite of previous inadequate surgery.

Radionecrosis.—Four patients have been subjected to exenteration for irradiation necrosis. In each instance, the operation was done with the realization that cancer might not be present, but with the decision that radionecrosis alone warranted the operation. One of these patients died suddenly five months postoperatively of unknown cause. The remaining three have remained in good health one, one, and four years since exenteration. Although the basic disease was carcinoma of the cervix, these patients are not included with the cervix cases in this analysis because carcinoma could not be identified in the surgical specimen. In considering the application of exenteration to this abnormality, it is important to balance two conflicting factors in the formulation of a decision: (1) carcinoma may indeed be present in spite of negative biopsies, and (2) the possibility that the distressing symptoms of radionecrosis may be relieved by a lesser operation than exenteration, such as colostomy. The selection of patients with radionecrosis for exenteration is again a matter of most careful judgment.

Carcinoma of the Vagina.—Exenteration was done for two patients with primary carcinoma of the vagina, one as the primary method of treatment of an advanced lesion with rectovaginal fistula, the second for an irradiation failure of carcinoma of the vaginal stump four years after complete hysterectomy. Both patients died of local recurrence and metastases within two years.

Lesions of Perineum.—One patient with advanced squamous-cell carcinoma of the anus with iliac lymph node metastases and another with carcinoma of Bartholin's gland with inguinal and iliac metastases were subjected to exenteration with approximately 18 months' survival before death from recurrence and metastases in each instance. A third patient with recurrent malignant melanoma of the vagina was treated in a similar manner and survived three and one-half years before succumbing to widespread metastases.

Miscellaneous Lesions.—The remaining lesions for which the operation has been used include three sarcomas arising in the pelvic organs (two uterus, one prostate). The patients uniformly did poorly, one being an operative fatality and the other two sur-

viving for less than a year before death from recurrence. One advanced carcinoma of the urinary bladder was removed by this technique, with the patient succumbing to recurrence 18 months later. Finally, a bizarre carcinoma of the ovary of 13 years' duration since initial diagnosis was found still to be limited to the pelvis and amenable to total removal by exenteration. This patient is well and without evidence of disease four and a half years later.

Comment

It is our opinion that the extended operation being considered has justified itself by the results thus far produced. This opinion seems further substantiated by the fact that the results represent the worst of our own operative mortality and patient selection. Without exception, all lesions were far advanced. Furthermore, our initial aggressiveness and enthusiasm led us to attempt resections that we would now refuse to do. With the benefit of past experience, the number of patients dying within the first year should steadily decline and the survival figures correspondingly improve. This is particularly true in reference to radiation failures of carcinoma of the cervix, which lesions should be recognized and considered for exenteration much more quickly than in the past.

The other lesions for which the operation has performed favorably are carcinoma of the rectum and endometrium and disabling radionecrosis.

In evaluation of the results of exenteration, attention must focus also on the factor of rehabilitation. It can be stated without equivocation that these patients can be restored to full activity and useful lives. One of our patients, a six-year survivor, has been divorced as a result of the operation. She is well and self-supporting at the present time. Others have had more minor degrees of marital difficulties. This factor certainly has not been of major importance and is not to be further considered after the operation has been explained to both husband and wife. If the operation is refused, it is taken as an indication that the individual was psychologically unsuited, though remarkably few have refused after the subject has been explained adequately. The operation is never urged upon a patient.

The selection of patients for the operation from the standpoint of physical findings is one of the greatest problems. One is torn between not wanting to refuse a patient who might be benefited and not wanting to accept a patient that is too likely to receive no benefit and to be "aggravated." To solve this dilemma, one can only rely on experience and judgment. Perhaps more reliance on the biological history of each individual lesion and attention to its histological "degree of malignancy" may be of help. These factors have been largely disregarded in the past. Unless we encountered the triad of lateral fixation, leg pain, and leg swelling, we have tended to consider each lesion worthy of operative exploration. The occasional exception to this triad has been the lesion "stony hard" with "bony fixation" to the lateral pelvic wall or sacrum. We do not hesitate to resort to examination under anesthesia to establish definitely the pelvic findings.

We still feel strongly that the operation of pelvic exenteration is one for continued study in institutions where a significant number of patients may be expected to accumulate. Only in this way can the true value of the procedure be determined and the mortality and morbidity rates be kept at an acceptable level.

Finally, the lesion being at the neck of a local funnel, it does not seem out of place to interject a note of dismay at the casual way malignancies of the cervix and uterus are managed in their early stages. If diagnosis was more regularly accurate before surgery, if surgery when indicated was more uniformly adequate, and if irradiation therapy of a uniformly high quality was administered, it is safe to say there would be far fewer patients for whom exenteration would have to be considered. And then, after removing the above "ifs" by elevation of standards of surgical and radiation therapy,

if the treatment failures were recognized, early pelvic exenteration would still provide the possibility of an appreciable salvage of patients otherwise doomed to an early death.

Summary

The results of pelvic exenteration performed on 118 patients are presented. Sixteen patients did not survive the operative procedure (13.5%). Eighty-six patients represented recurrent or advanced carcinoma of the cervix. The operative mortality of the cervix carcinoma group was 12 in 86 (14%). There were 4 operative deaths in 32 patients with other lesions (12.5%). The over-all operative mortality in the past three years has been 5 deaths in 61 operations (8.2%). Of all cervix patients, 35% are dead of the operation or of recurrence in the first 12 months after operation. Of all cervix patients operated upon three years or more ago, 23% are alive and well. Of 10 cervix patients operated upon over five years ago, 4 are alive and well without evidence of disease and leading fully active lives. These figures are interpreted to indicate that the procedure has been of definite benefit in the treatment of carcinoma of the cervix and should be continued for further evaluation and study. The small group of patients resected for rectal and endometrial carcinoma and for radionecrosis seem to indicate that the operation may be of benefit for selected lesions of this type. Survival in relation to extent of physical and pathological findings is discussed.

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Radical Surgery in Advanced Carcinoma of Intra-Abdominal Organs

Therapeutic Achievements

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Carcinoma of the stomach, colon, rectum and the biliary ducts is a challenging problem. This challenge is greatly multiplied whenever the carcinoma leaves the site of its origin and invades a neighboring organ or organs. When such a situation is encountered at laparotomy, the surgeon must evaluate resectability against (1) technical limitations, (2) risk to the patient, and (3) the estimated physical and physiological defect to be inflicted by the proposed operation.

Early diagnosis followed by proper treatment has been constantly emphasized as the best existing weapon against cancer. The logic of the statement and the desirability of such an attitude are obvious and unchallenged. However, the condition of early diagnosis of cancer cannot always be obtained. Many patients, for various reasons, report for definitive treatment only when the disease has spread beyond the perimeter of the original site of the neoplasm.

The need to care for these patients is an adequate stimulus to undertake the radical surgery described in this presentation. The surgical philosophy emphasized in this writing is fundamentally an expression against inadequate cancer surgery and against an abdicable declaration of cancer inoperability.

An example of inadequate cancer surgery is the periodic substitution of simple mastectomy for radical procedure in the case of carcinoma of the breast. Adequate resection of cancer of the sigmoid colon and the proximal rectum is often compromised in an attempt to preserve the sphincter mechanism. Wangensteen and co-workers,[1] Bricker and co-workers,[2] and Brunschwig [3] have presented convincing results of the value of well-directed radical cancer surgery.

A series of 50 cases is presented for the purpose of evaluating the therapeutic achievements in advanced carcinoma of intra-abdominal organs.

The reported cases fulfill at least one of the following requirements:

1. The neoplasm involves more than one organ.
2. The neoplasm has been declared inoperable:
   (*a*) without laparotomy
   (*b*) at laparotomy.
3. Diagnosis delayed or not established.
4. Inadequate cancer resection.

The analysis of the tabulated results indicates that in 12% of these 50 patients the condition was declared inoperable at laparotomy, and in 18% it was so declared without the benefit of laparotomy. In all but 2 of these 15 patients the neoplasm was found resectable by us. Two patients, who had been refused surgery elsewhere because of diagnosed inoperable lesions, are alive today, 13 years after surgery.

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The study of the various tabulations further indicates that 13 patients or 26%, were treated elsewhere for conditions other than carcinoma. The errors in diagnosis ranged from "irritable bowel" to "benign peptic ulcer." Of this group, in only one patient was the cancer not resectable.

Eleven patients, or 22%, reported in with early recurrence at the site of the original neoplasm removed by surgery elsewhere. It was believed that the recurrence was due to inadequate operation because of the limited "local resection." This group gave poor results upon reoperation. None of them attained a five-year survival.

The brief survey of the therapeutic achievements indicates that 2 of the 50 patients are alive and well 15 years after radical surgery; 6 patients survived 10 or more years, and 11 patients, or 22%, survived 5 or more years. This rate of five-year survival is slightly higher than that reported for carcinoma of the stomach. It would, therefore, appear that statistically multiple organ resection is justifiable for advanced carcinoma of intra-abdominal organs.

TABLE 1.—*Summary of Results in Multiple Organ Resections in Advanced Carcinomas of the Colon and Rectum*

Patient	Sex	Age, Yr.	Diagnosis	Operation	Survival Time and Results
1	F	32	Ca. sigmoid, multiple polyposis	Resection of sigmoid, colon, partial resection of abdominal wall	2 yr.; died of metastases
2	M	36	Ca. sigmoid, multiple polyposis	Resection of sigmoid, colon, partial resection of abdominal wall	2 yr.; died of metastases
3	M	68	Ca. sigmoid	Left hemicolectomy, splenectomy	5 days; died of peritonitis
4	F	67	Ca. sigmoid	Left hemicolectomy, splenectomy	10 yr.; alive and well
5	F	51	Ca. splenic flexure	Left hemicolectomy, splenectomy	8 yr.; alive and well
6	F	68	Ca. transverse colon	Resection of transverse colon, partial hepatectomy	1 yr.; died of liver metastases
7	M	48	Ca. cecum; ca. splenic flexure	Subtotal colectomy, total left hepatic lobectomy	16 yr.; alive and well
8	M	72	Ca. ascending colon; duodenal obstruction	Right hemicolectomy, partial gastrectomy, pancreatoduodenectomy	11 mo.; died of metastases
9	M	46	Ca. ascending colon, duodenocolic fistula	Right hemicolectomy, partial gastrectomy, pancreatoduodenectomy	2½ yr.; died of metastases
10	M	63	Ca. splenic flexure, obstruction	Colostomy, left hemicolectomy, partial gastrectomy, partial pancreatectomy, resection of ¼ of left diaphragm, splenectomy	6 yr.; alive and well
11	M	55	Ca. sigmoid, invasion of perirenal fat	Left hemicolectomy; perirenal fat, extensive resection of posterior parietal peritoneum	7 mo.; alive and well
12	M	55	Ca. sigmoid with perforation	Combined abdominoperineal resection, part of left ureter	Urinary fistula; left nephrectomy 1 yr. metastases; second look resection of pelvic floor, part of rt. ureter and ureterocystoneostomy; 1½ yr.; alive

TABLE 1.—*Summary of Results in Multiple Organ Resections in Advanced Carcinomas of the Colon and Rectum*—Continued

Patient	Sex	Age, Yr.	Diagnosis	Operation	Survival Time and Results
13	M	67	Ca. splenic flexure with invasion of diaphragm	Left hemicolectomy, partial gastrectomy, splenectomy, partial resection of left diaphragm	1 ½ yr.; alive and well
14	F	63	Recurrent ca. sigmoid with metastases to small bowel and body of uterus	Partial resection of small bowel, panhysterectomy, colostomy	4 mo. alive; second look, not able to inspect primary lesion
15	F	59	Ca. rectosigmoid with invasion of uterus and small bowel	Left hemicolectomy, partial resection of ileum, total hysterectomy, salpingo-oophorectomy	6 mo.; died of diffuse metastases
16	F	59	Recurrent ca. sigmoid with metastases to small bowel	Re-resection of sigmoid colon, partial resection of small bowel end-to-end anastomoses	6 mo.; alive with recurrence at anastomoses
17	F	65	Ca. rectum	Combined abdominoperineal; total hysterectomy; bilateral salpingo-oophorectomy	13 yr.; alive and well
18	F	64	Ca. rectum	Combined abdominoperineal; total hysterectomy; bilateral salpingo-oophorectomy	13 yr.; alive and well
19	F	59	Ca. rectum	Combined abdominoperineal; total hysterectomy; bilateral salpingo-oophorectomy	3 yrs.; has metastases, alive
20	F	58	Ca. simoid	Resection of sigmoid, ½ of urinary bladder	4 yr.; died of liver metastases
21	M	61	Ca. sigmoid	Resection of sigmoid, ½ of urinary bladder	5 yr. alive, pulmonary metastases; left lobe lobectomy, lived 2 yr. longer; died 7 yr. after operation from pulmonary metastases.
22	M	66	Ca. sigmoid	Resection of sigmoid, ½ of urinary bladder	3 yr., died of peritoneal and liver metastases
23	M	67	Ca. rectum	Combined abdominoperineal; part of perianal area; inguinal glands	1 yr.; died of metastases
24	M	56	Ca. rectosigmoid	Combined abdominoperineal; partial resection of abdominal wall	1 yr.; died of metastases
25	M	63	Ca. rectum	Combined abdominoperineal; second stage resection of perianal area	3 yr.; died of metastases
26	F	70	Ca. rectum	Combined abdominoperineal; part of vagina	5 yr.; alive and well
27	F	60	Ca. rectosigmoid	Resection of sigmoid, adjacent peritoneum, psoas muscle	8 yr.; alive
28	M	50	Ca. rectum, liver metastases	Combined abdominoperineal resection	4 yr.; second look; cholecystectomy; more extensive liver metatases; survived 6 yr.; died of liver metastases
29	F	65	Ca. rectum with regional metastases	Resection of cecum, terminal ileum, both ovaries, tubes, uterus, sigmoid colon, and proximal rectum	1 ½ yr. alive; second look and resection of distal rectum, no metastases found; alive and well
30	F	65	Ca. rectum with extension into rectovaginal septum and perineum	Combined abdominoperineal resection. Second stage: resection of posterior vaginal wall; perineum and coccyx. Third stage: subtotal vulvectomy and part posterior perineum	1 yr., 6 mo.; recurrence in posterior vaginal wall; 1 yr., second recurrence in posterior vaginal wall 1 yr. 6 mo.

TABLE 1.—*Summary of Results in Multiple Organ Resections in Advanced Carcinomas of the Colon and Rectum*—Continued

Patient	Sex	Age, Yr.	Diagnosis	Operation	Survival Time and Results
31	M	60	Ca. rectum with liver metastases, healed exploratory abdominal wound	Combined abdominoperineal resection of rectum	1 mo.; alive and well, free of pain
32	M	44	Ca. stomach with extensive lymph metastases	Total gastrectomy, splenectomy, omentectomy, part of transverse colon and part of pancreas	17 yr.; alive and well
33	F	60	Lymphosarcoma of stomach with healed rupture of malignant ulcer and metastases to abdominal wall	Total gastrectomy, splenectomy, omentectomy, part of abdominal wall	8 yr.; then developed pulmonary metastases; died following left lower lobe lobectomy
34	F	65	Ca. stomach with metastases to lymph glands	Total gastrectomy, omentectomy, splenectomy and part of pancreas	4 yr.; died, cause not determined
35	F	70	Ca. stomach with metastases to regional glands	Subtotal gastrectomy, splenectomy, partial pancreatectomy, omentectomy	10 yr.; alive and well
36	M	69	Ca. stomach with metastases to regional glands	Subtotal gastrectomy, splenectomy, partial pancreatectomy, omentectomy	1 hr.; died from tracheal aspiration
37	F	50	Ca. stomach (linitis plastica)	Total gastrectomy, partial esophagectomy, splenectomy, omentectomy	1 yr., 3 mo.; died of extensive cutaneous, pulmonary, and bony metastases
38	F	52	Ca. stomach with metastases	Total gastrectomy, splenectomy, omentectomy, left hepatic lobe lobectomy	6 mo.; alive with extensive metastases
39	F	75	Ca. stomach with extension into transverse colon	Subtotal gastrectomy, transverse colon colectomy and omentectomy	6 mo.; alive and well
40	F	54	Ca. stomach (linitis plastica)	Gastrectomy and splenectomy	1 yr., 4 mo.; alive with metastases
41	M	65	Ca. stomach 3 yr. duration	Partial gastrectomy	1 yr., 4 mo.; alive and well
42	M	39	Ca. stomach with 3 previous exploratory laparotomies	Biopsy only	4 mo.; died of metastases
43	M	63	Ca. stomach with massive local extension	Jejunostomy	Survived 3 wk.
44	F	42	Ca. of ampulla of Vater incompletely removed by local excision	Pancreatoduodenectomy	6 mo.; alive and well, gained 12 lbs. in wt.; no steatorrhea
45	M	38	Ca. of secondary division of rt. intrahepatic bile duct	Partial rt. hepatic lobectomy, cholecystectomy, resection of hepatic and common ducts	1 yr., 6 mo.; alive and well
46	F	65	Ca. of gall bladder with postoperative biliary fistula	X-ray therapy; cholecystectomy; partial hepatectomy; Roux-Y choledochojejunostomy	8 mo.; died of metastases
47	F	80	Ca. of pancreas, old healed cholecystectomy	Roux-Y hepatic duct-jejunostomy	14 days; died of liver failure
48	F	50	Ca. of gall bladder	Cholecystectomy and partial right lobe hepatectomy	1 yr.; second look; metastases to intestines; resection of bowel and omentum; died 2 mo.

TABLE 1.—*Summary of Results in Multiple Organ Resections in Advanced Carcinomas of the Colon and Rectum*—Continued

Patient	Sex	Age, Yr.	Diagnosis	Operation	Survival Time and Results
49	F	56	Ca. of gall bladder	Cholecystectomy and partial right lobe hepatectomy	4 mo.; died of metastases
50	F	54	Ca. head of pancreas	Pancreatogastroduodenectomy, partial colectomy	6 mo.; died of liver metastases

In pursuing these radical operations, the following factors have been noted:

1. The neoplasm must be within the orbit of resection in continuity.
2. There must be wide exposures to facilitate exploratory dissections.
3. The exploratory dissections are utilized to reveal hidden resectability.

The idea of exploratory dissections must be further emphasized. This initial dissection must be performed without destruction of the blood supply. The operation can be terminated without harming the patient if the exploratory dissection reveals the mass to be inoperable.

Out of the total experience with radical cancer surgery, two surgical procedures were developed and successfully utilized. The first of these is an operation devised for carcinoma of the splenic flexure with extension into the left diaphragm. The surgical procedure. One has now survived 6 years in good health, and the second patient is well 18 months after the operation.

The second procedure deals with the modification of total gastrectomy. The stomach is prepared for total resection in the usual manner. The lymphatic nest at the celiac axis artery is cleaned out after reflection of the stomach. The spleen, the distal one-half or one-third of the pancreas, the retropancreatic nodes, and the greater omentum are all resected with the stomach, but a portion of the cardia of the stomach is used for a Billroth I anastomosis. This gives the new stomach a maximum volume capacity after "total" resection. This procedure is illustrated in Figure 3. In Figure 4 the procedure was combined with left hepatic lobe lobectomy. A postoperative roentgenogram of such a "total gastrectomy" is illustrated in Figure 5.

TABLE 2.—*Summary of Results*

	No.	Per Cent
Cases	50	100
Hospital mortality	4	8
Patients surviving 15 years	2	4
Patients surviving 10 or more years	6	12
Patients surviving 5 or more years	11	22
Patients surviving 2 or more years	21	42
Patients surviving 18 months or longer	26	52

TABLE 3.—*Statistics on Five-Year Survival Cases*

Organ	Total No. of Cases	5-Yr. Survival	
		No.	Per Cent
Colon	20	6	30
Rectum	11	3	27.2
Stomach	12	3	25
Biliary ducts and pancreas	7	0	0

cedure devised consisted of left hemicolectomy with splenectomy and resection of part of the diaphragm and pancreas. This operation is adequately described in Figures 1 and 2. Two patients underwent the above pro-

The most satisfactory, and rather common, procedure was an en bloc resection of the sigmoid colon and total hysterectomy with bilateral oophorectomy. This operation

TABLE 4.—*Surgery Performed in This Series After Patients Had the Following Experiences Elsewhere*

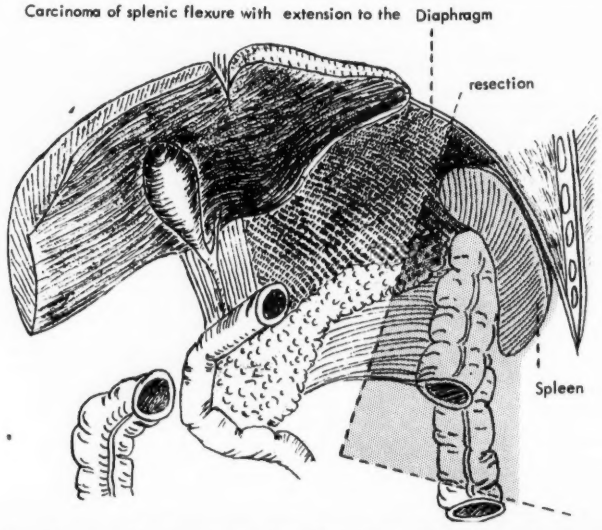
	No.	Per Cent
Total Number of Cases	50	100
Neoplasm has been declared inoperable	15	30
(*a*) Without laparotomy	9	18
(*b*) With laparotomy	6	12
Diagnosis delayed or not established	13	26
Inadequate cancer resection	11	22
Patients diagnosed and referred for definitive surgery without delay	11	22

was performed six times with good results. An illumination of the usual findings is depicted in Figure 6.

The spread of carcinoma of the sigmoid colon or rectum into the urinary bladder, as illustrated in Figure 7, likewise gave good results following partial resection of the urinary bladder. One patient developed a pulmonary metastasis (Fig. 8) five years after combined resection of sigmoid colon and one-half of the urinary bladder. This patient survived an additional two years following left lower lobe lobectomy (Fig. 9).

TABLE 5.—*Spread of Carcinoma of Colon and Rectum by Infiltration*

Organ Infiltrated	No. of Cases	Resectable	Mortality	5-Yr. Survival	
				No.	Per Cent
Urinary bladder	4	4	0	1	25
Uterus and ovaries	6	6	0	2	33.3
Pancreas	2	2	0	0	0
Splenic area and diaphragm	5	5	1	3	60
Intestine, mesentery, peritoneum	6	6	0	1	16.6
Perineum, vagina	4	4	0	1	25
Liver	4	4	0	2	50



Left hemicolectomy with splenectomy and resection of part of diaphragm and pancreas.

Figure 1

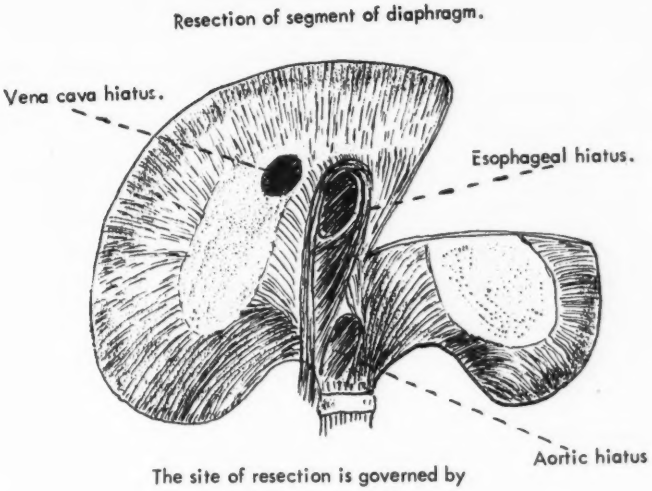

Resection of segment of diaphragm.
Vena cava hiatus.
Esophageal hiatus.
Aortic hiatus
The site of resection is governed by
the site of neoplastic involvement.

Figure 2

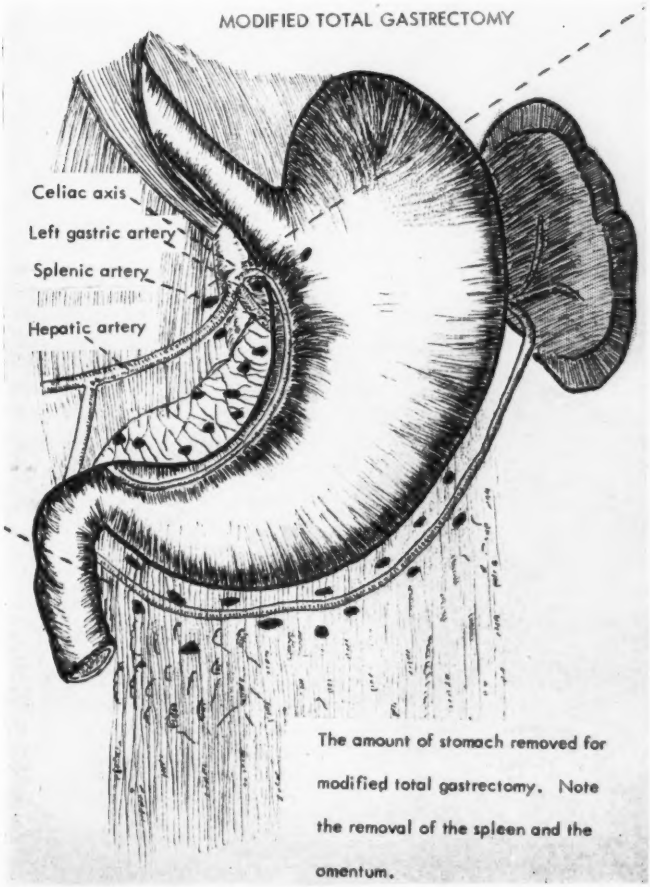


Figure 3

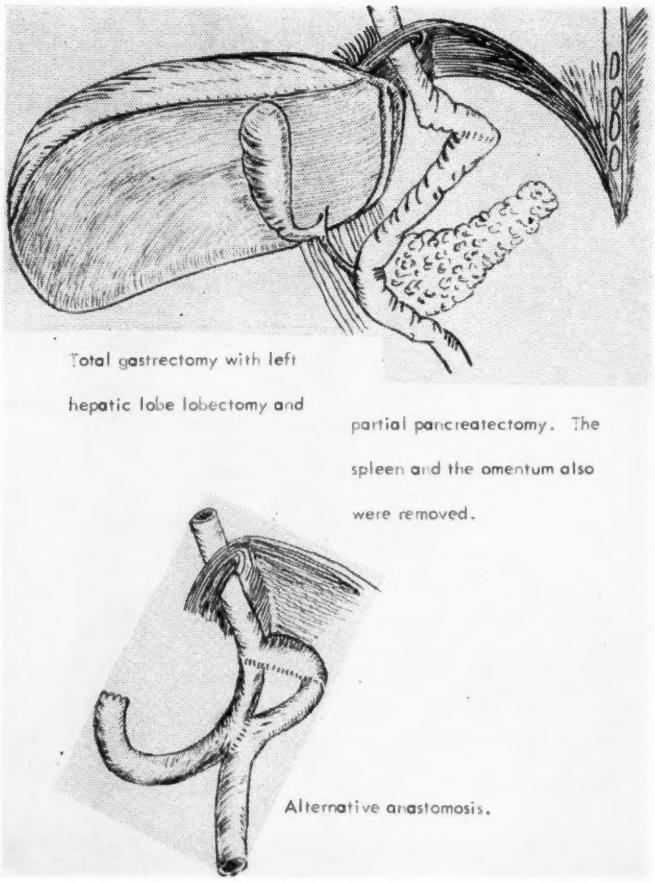


Figure 4

Summary

The experiences and results obtained in 50 cases of multiple organ resection are probably no different from those encountered by other general surgeons. However, we hope our experiences will serve as encouragement to others willing to devote the extra time and effort necessary for these radical operations.

Every intra-abdominal cancer operation may reveal itself at laparotomy as a problem of multiple organ resection. The surgeon conducting these operations must not only be equipped with the proper skill, but also must be willing and able to set aside limitless time for the execution of the adequate cancer procedure. In an earlier publication,[4] one of us has pointed out that multiple organ resection extends the resectability of cancer of the colon or rectum by 9%. This is an adequate reward for the extra time and effort expended.

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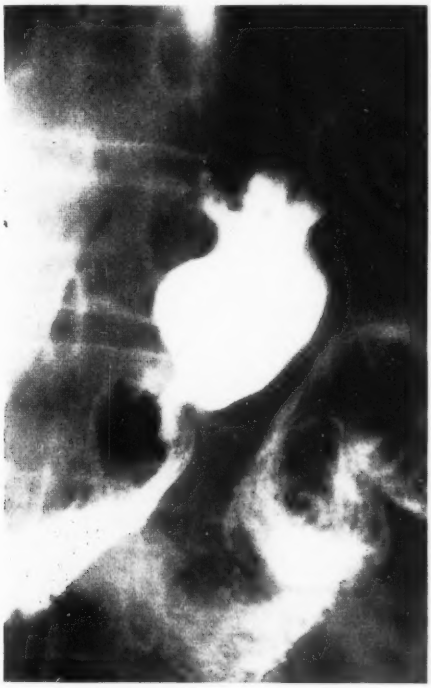

Fig. 5.—Postoperative roentgenograms following modified total gastrectomy.

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Figure 6

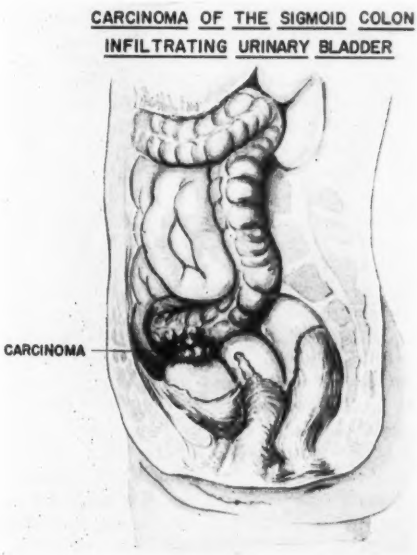

Figure 7

Fig. 8.—Roentgenogram showing a solitary metastasis in the left lower lobe from carcinoma of the sigmoid colon.

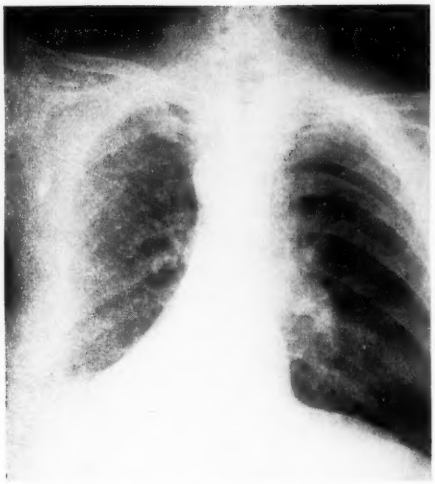

Fig. 9.—Roentgenogram following left lower lobe lobectomy for carcinoma metastases from sigmoid colon.

DISCUSSION

ON PAPERS BY DRS. BRICKER, BUTCHER AND MCAFEE; PROHASKA, NELSEN, AND EVANS

DR. DARRELL A. CAMPBELL, Ann Arbor: I wish to comment briefly on the paper by Drs. Bricker, Butcher, and McAfee.

Nearly 10 years ago, at the Wayne County General Hospital, we embarked upon a short program to evaluate pelvic exenteration. All of our cases had hopeless postradiation carcinoma of the cervix with either vesicovaginal or vesicovaginorectal fistulae.

Subsequent to carrying out 15 of these cases, we allowed sufficient time to elapse to allow us to evaluate the operation.

Three patients succumbed in the early postoperative period. One patient survived four years. A number of patients died after two years. The high degree of morbidity, the prolonged and multiple hospitalizations, and the depletion of personal finances forced us to abandon this operation.

Dr. Bricker and his group this morning, I believe, have presented the statistics which are obviously in favor of the operation in their hands. Following our evaluation, it was our belief that there was in all probability such a thing worse than death, and survivors of the operation in our hands were examples of such instances.

In view of the obviously low complications presented by Dr. Bricker, I am sure that many of us will be forced to reassess the importance of this operation in the future.

DR. ROBERT BERRY, Ann Arbor: I believe that both groups of authors are to be commended for their aggressive attitude toward and results with these types of advanced cancer. We all realize that surgery is not the ultimate answer to cancer and yet, in 1956, it is the best weapon that we have. Criticism leveled at multivisceral operations for cancer, appearing in the lay as well as surgical journals, cannot be universally justified because good results are obtained from such surgery. It must be admitted, however, that certain limiting factors do exist that are not well understood, and particularly is this true when the nature of the biological malignancy of the cancer cell present in an individual case is considered.

[Slide] This specimen was removed from a 42-year-old man whose cancer of the stomach had invaded the head of the pancreas. The operation was total gastrectomy, splenectomy, total pancreatectomy, and duodenectomy. When combined with excision of the celiac nodes, this represents a fairly maximum effort to eradicate the local cancer.

[Slide] Special studies were done to evaluate the lymphatic spread demonstrated that 19 out of 72 nodes isolated showed metastatic involvement.

[Slide] Microscopically this was a highly undifferentiated scirrhous carcinoma. This man survived less than four months and then died of massive recurrence despite apparent complete removal by radical surgery. It is not unreasonable to assume that his cancer was made up of cells possessing a high biologic malignant potential and that any operation compatible with life would not help him. Certainly, however, this does not mean that we should stop trying to eradicate cancer by such operations.

Detailed lymph node studies of advanced cancers of the stomach have suggested that when the lesion involves the upper half and/or the greater curvature frequent involvement of the pancreaticobinal nodes occurs. As pointed out by Rouviere, however, the nodes at the splenic hilus and along the left gastroepiploic fold demonstrate inconsistency of numbers and locations.

Nodes along the splenic artery tend to be more constant.

Because of the metastatic involvement of nodes along the splenic artery in certain of our specimens, it is felt that the above type of lesion is best treated by ligation of the splenic artery at its origin from the celiac axis and removal of the distal half or third of the pancreas together with the spleen to facilitate excision of this portion of the pancreaticolienal nodes.

As demonstrated today, multivisceral operations for cancer can be justified. The treatment of cancer of the pancreas is not routine cholecystojejunostomy. The salvage rate from radical surgery may not be great, but it is better than no

salvage at all. There are enough good results to justify continued effort to eradicate cancer in this manner.

DR. C. ALAN MCAFEE: I should like to thank Dr. Campbell for his remarks. We thought it was better to discuss only long-term survivals. However, some of the patients who have lived for two and three years have been persons with far-advanced carcinomas who have gone home to take care of young children. The palliation achieved has certainly been worth while. Marital disruption has not been a great problem, though we will admit that two husbands have left their wives.

DR. JOHN VAN PROHASKA, Chicago: I should like to thank Dr. Berry for his encouraging remarks. There are, of course, great differences in the carcinomas of the stomach. Some patients survive many years after a simple subtotal gastrectomy; others die within a few months after a radical total gastrectomy.

The patient on whom I performed a total gastrectomy, partial pancreatectomy, and left hepatic lobectomy, as well as splenectomy and omentectomy died six months after her operation. At the completion of her radical operation, there was no visible or palpable evidence of cancer. Six months later her peritoneal surfaces were everywhere studded with carcinoma nodules, some of which measured as much as 2 cm. in diameter. One wonders how so much cancer could have grown in such a short period of time.

I believe it is acceptable to say that there are either differences in the virulence of the cancer or differences in the resistance of the host of the disease.

Intestinal Injuries Following Irradiation of Pelvic Viscera for Malignancy

WILLIAM REQUARTH, M.D.
and
STUART ROBERTS, M.D., Decatur, Ill.

The occurrence of irradiation lesions in the intestinal tract subsequent to the treatment of malignancies is well known. In a survey of intestinal obstruction at the University of Illinois Hospitals for the period between Jan. 1, 1947, and December, 1955, twelve cases of intestinal injury secondary to pelvic irradiation for malignant disease of the reproductive organs were encountered and are the subject of this report. All were females and all showed, among other manifestations, partial or complete obstruction of the bowel. There were four deaths, a mortality rate of 33%. Our purpose here is to review these cases, point out the diagnostic features of benign irradiation stricture, and discuss methods of treatment.

Many reports have appeared in the literature regarding the destructive effects of pelvic irradiation for malignancy. Buie and Malmgren [4] discussed 88 cases of radiation damage to the rectum and first used the term factitial proctitis to describe the lesion. Todd [26] studied a series of cases with rectal ulceration following irradiation of the cervix. Bacon,[2] Healy and Frazell,[11] Feder and Leichtling,[8] and Wigby [25] reported post-irradiation complications involving the rectum as well as other pelvic viscera. Jones [13] treated surgically 15 cases of benign stricture of the intestine after irradiation. Although the rectum is usually involved because of its position adjacent to the cervix, other structures, especially the ileum, may be involved. Animal experimentation by Desjardins [7] indicated that the small intestine was more sensitive to the effects of x-ray than the colon.

Distribution of intestinal injuries following pelvic irradiation for malignancy.

Incidence

The incidence of mechanical bowel obstruction following irradiation is difficult to determine from the literature (Table 1). In the period covered by this study, 479 cases submitted to irradiation for pelvic malignancy at the University of Illinois Hospitals. Of the 12 cases studied, 10 were treated in this institution and 2 elsewhere, an incidence of benign stricture of 2.1%.

Submitted for publication April 3, 1956.

From the Department of Surgery, University of Illinois College of Medicine, Chicago.

Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 25, 1956.

Wigby [25] reports 7.9% of his cases treated for carcinoma of the cervix required colostomy for rectal stricture; White [23] records two cases of acute intestinal obstruction but does not mention incidence. Maas [15] noted that 8% were followed by stricture, and Jones [18] found 1.8% stricture in 800 cases of treated carcinoma of the cervix. Healy and Frazell [11] found 1.6% rectal stricture and no obstructions; Aldridge [1] found 12.1% strictures after carcinoma of the cervix and none after carcinoma of the uterus. The rectum and rectosigmoid were the most frequent sites because of their proximity to the cervix. Since it is now accepted that no cures result unless deep therapy is used in maximum dosage, organs adjacent to the cervix and uterus will continue to be damaged unless a method for shielding is devised.

TABLE 1.—*Incidence of Stricture Following Pelvic Irradiation*

	No. of Cases Treated	Strictures,%
Wigby [25]	77	7.9
Maas [15]	600	8
Jones [18]	800	1.9
Healy [11]	551	1.6
Aldridge [1]	189	12.1
Requarth & Roberts [19]	479	2.1

Relation of Complications to Total Irradiation

An attempt was made to determine the relationship between total irradiation and the interval and character of the complications. Unfortunately, such a comparison could not be made. Doses were often given in terms of skin dose rather than amount delivered to the neoplasm. Radium, measured in milligram-hours, was frequently used in conjunction. In two cases the exact amount of irradiation was unknown, and in one case the betatron was used. Doses varied from 4750 to 19,400 and 50 to 8400 mg.-hr. of radium.

Individual Susceptibility to Irradiation

There is apparently a wide variation in individual susceptibility to irradiation, and this further tends to make comparison of complications in relation to dose invalid. Deaths have been reported within days after relatively low doses in persons apparently sensitive to x-ray. Todd [26] reported an early death after minimal therapy, while Mulligan [16] had a fatality 14 days after 4200 r was delivered to the cervix. Autopsy revealed "x-ray intoxication." Cathie [5] reported two fatalities after 1500 r, both distinguished by severe diarrhea and diffuse ulceration of jejunum and ileum. He concluded that any severe diarrhea which occurs early in treatment is a cause for grave concern.

Clinical Manifestations

The mucous membrane of the rectum is more sensitive to x-ray than adjacent structures, and because of its anatomical position early damage occurs. The initial reaction is one of acute inflammation with bloody diarrhea, pain, and tenesmus. Digital examination and proctoscopy are quite painful. There is hyperemia and swelling of the anterior wall of the rectum corresponding to the

TABLE 2.—*Late Complications Noted in Twelve Cases* *

	Stricture		Fistula	Necrosis Abdominal Wall	Radiation Enteritis
	Rectum Rectosigmoid	Ileum			
Chronic	7	1	2	1	1
Acute	2	3			

* Three cases had more than one complication.

approximate position of the cervix, the degree varying with the person. The process may subside after six or eight months, after which the mucosa becomes pale and atrophic.

TABLE 3.—*Time from Completion X-Ray to Onset Late Symptoms*

	6 Mo.	6-12 Mo.	More Than 12 Mo.
Ileum	1	1	2
Rectosigmoid	..	3	3
Rectum	1	2	
Total	2	6	5

The delayed manifestation of irradiation injury is chiefly an ulcerative process or the sequelae of ulceration. In the present series the average time of onset of late symptoms was 3 years, the shortest interval being 3 months and the longest 15 years (Table 3). Jones [14] and Frank and Pohle [9] reported cases in which symptoms did not occur until eight years after therapy. Gardner and Anlyan [18] noted a stricture of the ileum 12 years after irradiation.

TABLE 4.—*Location and Type of Obstruction* *

Location	Acute	Chronic	All Cases
Ileum	3	1	4
Rectosigmoid	2	4	6
Rectum	..	3	3
	5	8	13

* One case had two obstructions.

As in other regions of the body, excess irradiation of the bowel produces secondary endarteritis and gradual withdrawal of blood supply to the area. This is followed by ulceration and scarring but not inevitably with stenosis. In this stage there is diffuse sclerosis of the tissues and on digital examination, in addition to stenosis, the tissues are hard and fixed. Such a lesion is difficult to differentiate from recurrent cancer except that much tenderness is present. In the cases reported here there were 13 strictures, 9 in the rectum and rectosigmoid and 4 in the ileum. The diagnosis of recurrent cancer was made in error in two cases. In two cases cancer existed concurrently with irradiation stricture, and therefore differentiation was impossible.

The incidence of injury to the small intestine during irradiation of the pelvis is not high. Wiley and Sugarbaker [20] found small bowel damage in 9 of 600 cases irradiated, and Waterman and Tracy [22] in 3 of 489 cases. In this series damage to the ileum occurred four times, three manifested by acute obstruction which required emergency surgery. In two of the four cases, the ileum was adherent in the pelvis at the site of previous surgery, an obvious contributory factor which has been noted by others.*

Of particular importance is the effect of irradiation enteritis in the absence of clinical evidence of obstruction. Case 10 had chronic abdominal pain and vomiting for eight years following an unknown amount of pelvic irradiation for carcinoma of the ovary. Repeated gastrointestinal x-rays were negative, and the patient was considered a psychopath until an abdominal mass became palpable. At celiotomy, several loops of ileum were found to be involved with irradiation enteritis. There was a partial stricture of the ileum which had not produced significant obstruction. After excision of the ileum and right colon, the patient was cured. Irradiation enteritis must be considered as a cause of chronic abdominal pain after radiation therapy.

Treatment

Colostomy alone or combined with other procedures was used in eight cases (Table 5). In two cases colostomy may have been unnecessary, but in the remainder there was sufficient obstruction to require this operation. Dilatation alone relieved one patient. The outlook is good for irradiation stricture, and repeated dilatations will frequently result in a cure.

Operations on the bowel other than colostomy were performed in five cases. Three

* References 17 and 24.

TABLE 5.—*Treatment in Twelve Cases* *

	Dilatation Only	Colostomy-Dilatation	Colostomy Only	Resection	Enteroenterostomy
Ileum	--	--	--	2	2
Rectosigmoid	--	1	5		--
Rectum	1		2	1	

* Three cases had more than one complication.

of these patients had acute obstruction of the ileum; one was resected with a good result, one had an ileocolostomy, and a third had an enteroenterostomy. This was later complicated by the formation of an enterovesicocutaneous fistula, suggesting that bowel involved by advanced irradiation enteritis should be excised. In two of the above cases it was noted that the loop of ileum had become attached in the region of the cul-de-sac and received large amounts of irradiation.

A fourth case had excision of the right colon and terminal ileum for radiation enteritis. Abdominoperineal resection of a benign rectal stricture was performed in one case. The operation was technically difficult owing to sclerosis of the pelvic tissues. Although resection is definitely indicated for strictures of the ileum, it is probably seldom indicated for strictures accessible to dilatation such as the rectum and rectosigmoid. Repeated dilatation of strictures in this region usually produces a cure.[1] In the presence of significant obstruction, a complementary colostomy may be necessary.

Summary

Twelve cases of intestinal injuries following irradiation for pelvic malignancy are presented. All patients were female, and all were irradiated for disease of the reproductive organs. There were four deaths, a mortality rate of 33%. All had benign strictures, there being evidence of chronic obstruction in eight cases and acute obstruction in five cases. One patient had persistent abdominal pain without clinical signs of obstruction.

The site of the stricture was rectum and rectosigmoid in nine cases and ileum in four cases. In two which involved the ileum, the loop was fixed in the region of the cul-de-sac and was apparently exposed to excessive irradiation.

No definite correlation could be made between total irradiation and the interval and character of the complications. There is apparently wide variation in individual susceptibility to irradiation.

Rectal ulceration, bleeding, and an obstructing pelvic mass are frequent sequelae to pelvic irradiation. The diagnosis of recurrent cancer should not be made in such cases in the absence of a positive biopsy.

Irradiation enteritis may cause chronic abdominal pain of obscure origin. Resection of involved bowel results in an immediate cure.

Colostomy is not advised for strictures of the bowel accessible to repeated dilatation except in the presence of a significant degree of obstruction. Dilatation alone will frequently result in a cure.

Resection of the rectum and rectosigmoid is not advised for strictures at this level.

Resection is advisable for benign strictures inaccessible to dilatation, such as ileum, and for bowel involved with irradiation enteritis with chronic abdominal pain as the chief symptom.

DISCUSSION

DR. G. ALAN LANE, Hamilton, Ont., Canada: I was very much interested in this paper because about 5 years ago, over the course of 18 months, I ran into an accumulation of these cases. We collected 14 cases in that period. One was a small bowel fistula between the ileum and uterus, another a small bowel obstruction, three were large bowel obstructions, and there were several cases of proctitis.

TABLE 6.—*Summary of Twelve Cases with Intestinal Injury Following Pelvic Irradiation*

Case No.	Location of Disease	Operation	Radiotherapy, Roentgens and Mg.-Hr.	Interval from Completion of X-Ray to Onset Significant Symptoms	Treatment	Outcome	Type of Obstruction	Remarks
1	Cervix, stump	Excision of cervix	11,500 r 50 mg.-hr.	15 yr. stricture rectosigmoid acute obstruction, ileum	Colostomy	Well June 1955	Chronic (recto-sig.); acute (ileum)	Ileum fixed to area of rectal surgery
2	Cervix	None	12,600 r 4,000 mg.-hr.	1 yr. obstructing mass in rectum "recurrent CA," no biopsy	Colostomy	Well July 1955	Chronic rectum	Diagnosis of recurrent CA error
3	Cervix	Panhysterectomy	14,760 r 2,000 mg.-hr.	6 yr. acute obstruction of rectosigmoid, stricture	Colostomy	Died CA, 1953	Acute rectosig.	
4	Uterus	Panhysterectomy	8,740 (betatron)	1 yr. stricture, rectosigmoid	Colostomy	Died CA, 1953	Chronic recto-sig.	
5	Uterus	Panhysterectomy	19,400 r	1 yr. stricture, sigmoid	Colostomy	Died CA, 1951	Chronic sigmoid	
6	Uterus	Panhysterectomy	13,100 r 3,800 mg.-hr.	1 yr. stenosis, ulceration, rectosigmoid, "CA sigmoid," no biopsy	Colostomy	Living and well Nov. 1955	Chronic recto-sig.	Diagnosis of sigmoid CA an error
7	Cervix	None	13,200 r 5,500 mg.-hr.	2 yr. acute obstruction rectosigmoid, stricture	Colostomy dilatation	Living and well Aug. 1955	Acute rectosig.	Colostomy closed; recovery with dilatation
8	Cervix, stump	None	6,580 r 6,300 mg.-hr.	3 mo. rectal stricture	Colostomy, abdominperineal	Living and well Aug. 1955	Partial rectum	
9	Cervix	None	8,500 r 4,500 mg.-hr.	4 mo. massive necrosis, abdominal wall; 7 mo. acute obstruction, ileum; 8 mo. entero-vesic-cutaneous fistula	Skin grafts, enteroenterostomy, res. fistula	Died in OR	Acute ileum	Ileum should have been resected 1st operation
10	Ovary	Hysterectomy, oophorectomy	Unknown	8 yr. abdominal pain, vomiting, G.I. x-ray neg., considered psychopath until abdominal mass palpated	Right hemicolectomy	Living and well Jan. 1956	Partial ileum	Radiation enteritis
11	Cervix	Panhysterectomy	4,750 r 3,500 mg.-hr.	1 yr. stricture, rectum	Dilatation	Living and well Jan. 1956	Partial rectum	
12	Cervix	None	11,182 r	5 mo. acute small bowel obstruction; 6 mo. rectovaginal fistula	Ileocolostomy	Living and well Jan. 1956	Acute ileum	Involved ileum fixed in pelvis

The point that I wish to emphasize is that in the last five years we haven't seen any more. I think that this brings out the fact that with careful treatment this complication must be exceedingly rare.

We have not changed our radiation dosage at all. There has been more careful technique used in packing of the vagina and separating the posterior fornix, but more particularly there has been a complete abandonment of the A. P. field for x-radiation. The juxtaposition of rectum and cervix in the A. P. field, of course, means that the rectum gets practically the same dose as the cervix. With the use of diagonal fields, a higher dose can be given to the cervix, sparing the rectum. I think that has been a very important factor.

Two small points: It certainly has been our experience that where small bowel is involved there has been a previous laparotomy. Occasionally strictures of the rectum do require operation, in our experience, and we have found that the transsacral approach has much to recommend it. It is not always easy, but transsacral resection of the stricture and anastomosis of the bowel leaving the sphincter mechanism intact may be possible when such a procedure would be extremely difficult from above.

DR. HOWARD COGSWELL, Tucson, Ariz.: I want to congratulate Dr. Requarth and thank him for reviewing this subject. I left a patient in the hospital with this complication when I left for Rochester. The patient is a woman whose symptoms make me want to ask Dr. Requarth a question.

This patient showed signs of nerve damage about seven years after extensive radiation for carcinoma of the cervix. This is manifested by lower extremity weakness, pain, paresthesias, anesthesias, with atrophy of the muscles of the buttocks and quadriceps. The radiotherapists tell me that radiation will not damage nerve tissue in the doses of radiation normally used. We have noted that this patient's total proteins remain about 4 gm. per 100 cc., although she has a good appetite and eats well. We have been able to raise her serum proteins to normal by transfusions and plasma, but this has been only a temporary improvement. Her blood calcium is likewise low.

Is it possible that the nerve damage that she manifests is due to lack of absorption from the radiated intestines, with the nerve damage being secondary to deficiency state of some type?

DR. WILLIAM REQUARTH, Decatur, Ill.: I think than in many of these cases, after a certain amount of time has elapsed, the sclerosis and fibrosis will soften. That might be the answer. I don't know the total answer for something like that.

Regarding abdominoperineal, we believe that it is not advisable if one can avoid it. Of course, there might be cases where something has to be done. The operation is difficult in the presence of radiation fibrosis, and we believe that strictures that are within reach of a dilator can usually be dilated, and over a period of time they will get relief.

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Innervation of the Sphincter of Oddi in the Dog

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Dysfunction of the sphincter of Oddi is assuming increasing importance because of its relationship to the painful sequelae which at times follow cholecystectomy and because of its possible etiologic significance in the production of pancreatitis. Information concerning the innervation of the sphincter of Oddi should be helpful in understanding its function and dysfunction.

In 1923 Westphal [11] described a choledochal sphincter made up of circular and oblique muscle fibers commencing just outside of the duodenal wall and continuing almost to the tip of the papilla of Vater. The tip of the papilla, he noted, was encircled by a separate iris-like circular muscle bundle, which he called the papillary sphincter. Weak electrical stimulation of the vagus nerve in the abdomen produced relaxation of the sphincter of Oddi, whereas strong vagal stimulation produced spasm of the choledochal portion of the sphincter. Sympathetic stimulation caused a relaxation of the choledochal sphincter and contraction of the papillary sphincter. These observations were made on cats, rabbits, and guinea pigs.

There is some doubt that this same arrangement of the sphincter exists in dogs. Boyden [2] stated that there was no ampulla of Vater in the dog and, therefore, no papillary sphincter except for a few terminal rings of muscle about both the bile and pancreatic ducts. In a recent article by Eichhorn and Boyden, however, the authors describe a terminal band of muscle in the dog which encloses both bile and pancreatic ducts, and which they identify as a sphincter ampullae even though the ducts empty separately.[5] Lueth [8] passed a cannula through the intramural portion of the sphincter of Oddi in the dog. He noted that when the cannula was just inside the orifice of the papilla, infusing fluid caused the ampulla to bulge before the orifice opened. He postulated a papillary sphincter and found that its resistance varied from 6 to 13 cm. of water. Mallet-Guy and co-workers,[9] also working with dogs, produced acute pancreatitis by stimulating the left splanchnic nerve in the abdomen. This could have resulted from obstruction of the pancreatic duct by a papillary sphincter, in addition to interference with the pancreatic blood supply.

There is ample evidence of a papillary sphincter in man surrounding the terminal 1 to 2 mm. of the papilla. Reflux of contrast material up the pancreatic duct occurs in approximately 30% of patients on whom operative cholangiography is performed. When sphincterotomy is indicated in patients showing reflux, the junction of the pancreatic and common ducts is frequently found to be within 1 to 2 mm. of the tip of the papilla. Kreilkamp and Boyden [7] found a papillary sphincter well developed, however, in only 2 out of 12 adults studied.

The existence of such a terminal papillary sphincter common to both the bile duct and

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the pancreatic duct and possibly under sympathetic control is important in explaining the etiology of some cases of pancreatitis. It also helps explain the efficacy of sphincterotomy in the treatment of pancreatitis reported by Doubilet and Mulholland,[4] though, as Bove [1] has pointed out, the operation should be called papillotomy.

The object of the present investigation was the cholangiographic demonstration of the different components of the sphincter of Oddi in the dog as shown by stimulation of sympathetic and parasympathetic nerves.

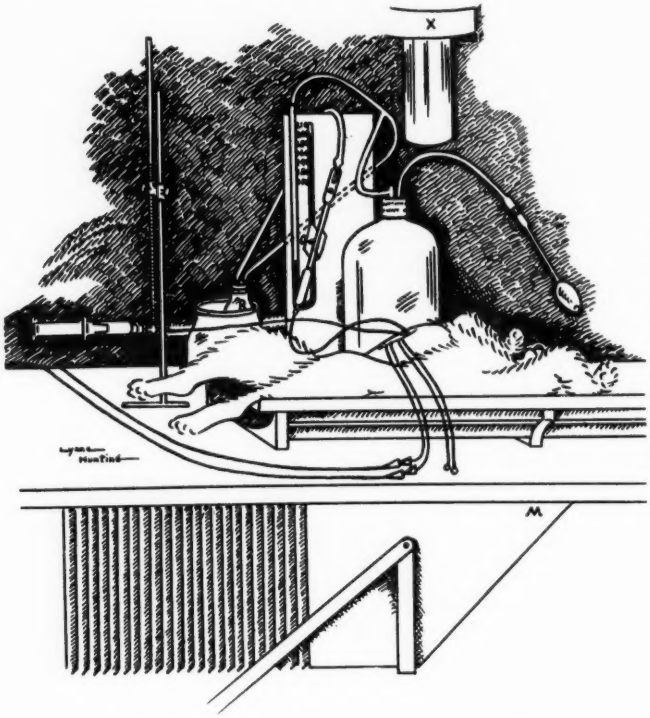

Fig. 1.—Animal positioned under x-ray tube (*X*) and over mirror (*M*) angled at camera. Electrodes connected to Grass stimulator. One polyethylene catheter connected to constant injection apparatus with acetrizoate (Urokon) resevoir (*R*) in water bath. Second polyethylene catheter connected to spinal manometer.

Method and Material

Healthy mongrel dogs averaging 30 to 40 lb. (13.6 to 18.2 kg.) were used in this investigation. These were anesthetized with intravenous pentobarbital (Nembutal) sodium 30 mg. per kilogram of body weight, and additional anesthetic solution was added as needed through a Lindeman needle fixed in a foreleg vein. Shielded silver electrodes were placed on the left splanchnic nerve between the diaphragm and the left celiac ganglion. Similar electrodes were also placed on the left vagus nerve below the diaphragm and above the branch of the left vagus going to the liver. Two fine polyethylene catheters (Clay Adams P. E. 90) were inserted into the common bile duct through the cystic duct and were fixed in place. One of these catheters was attached to a spinal manometer filled with saline for observing and recording pressures in the common duct. The other catheter was attached to an apparatus for the constant injection of a radiopaque contrast media (70% sodium acetrizoate [Urokon]).

The dogs were positioned supine on the x-ray table with varying degrees of right posterior obliquity to offset the sphincter of Oddi from the duodenum as determined by scout films (Fig. 1). Following a control period of injection at a constant rate, which varied in different experiments from 10 to 40 drops a minute, strong and weak stimuli were applied to the respective electrodes by means of a Grass stimulator. The stimuli consisted of monophasic square-topped pulses with a frequency of 175, duration of 0.3 msec., and voltages varying from 5 volts for weak stimuli to 20 volts for strong stimuli. Cineroentgen movies as well as plain films were taken of the

sphincter of Oddi during the control periods and those of stimulation.

Results

Experiments on 13 dogs comprise the material for this report. Three of this group were discarded for technical inadequacies such as lack of recording of intraductal pressures during injection of the contrast material. Of the 10 remaining experiments, 8 gave fairly consistent results, whereas in the remaining two, the results were reversed.

After a control period without stimulation (Fig. 2), strong splanchnic stimulation at from 10 to 20 volts caused a contraction of the choledochal sphincter in two dogs, with a mild increase in intraductal pressure in one and no pressure change in the other. In four experiments, the papillary portion of the sphincter appeared narrow, and intraductal pressure rose from 7 to 13 cm. of saline (Fig. 3). The sphincter was relaxed in the remaining experiments, except in one in which it could not be seen owing to contrast material in the duodenum.

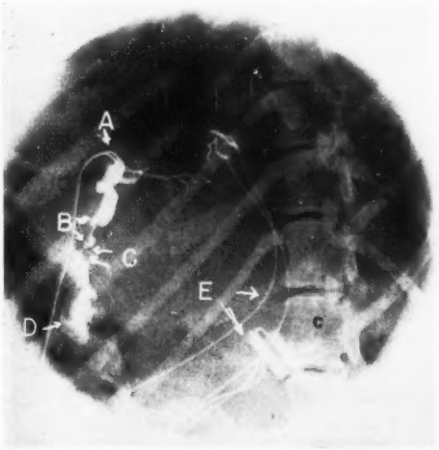

Fig. 2.—Control. *A*, polyethylene catheters in common bile duct; *B*, choledochal sphincter; *C*, papillary sphincter; *D*, duodenum; *E*, electrodes on left vagus and left splanchnic nerves. Sphincter of Oddi (*B* plus *C*) open with contrast media in duodenum.

Fig. 3.—Strong splanchnic stimulation. Choledochal sphincter relaved with narrowing of papillary portion. Moderate filling of intrahepatic ducts.

Fig. 4.—Weak vagal stimulation. Sphincter partly cut off and obscured by catheters; contrast material in the duodenum. Increased filling of the intrahepatic ducts.

Weak vagal stimulation at from 2 to 5 volts caused no response in six dogs, and an incomplete closure of the choledochal sphincter in four (Fig. 4) with rises in intraductal pressure ranging from 1 to 6 cm. of saline.

Strong vagal stimulation at from 10 to 20 volts caused marked contraction of the choledochal sphincter in seven dogs with rises in intraductal pressure varying from 5 to 28 cm. of saline (Fig. 5). In one ani-

mal, increased respirations pulled the polyethylene catheter out of the common duct before films were made. In the remaining two experiments, the same stimulation caused relaxation of the sphincter with a drop in intraductal pressure of 4 to 5 cm. of saline.

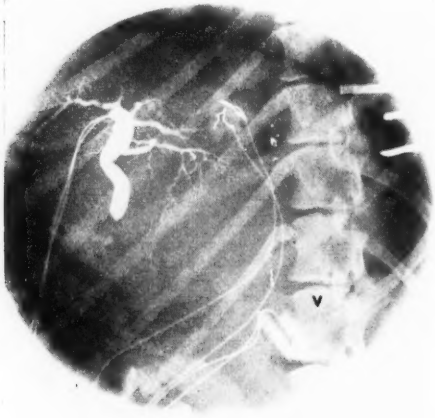

Fig. 5.—Strong vagal stimulation. Sphincter completely cut off with no contrast material in the duodenum; dilatation of the common duct and marked filling of the intrahepatic ducts.

Comment

The variation in the response of the sphincter of Oddi to electrical stimulation of sympathetic and parasympathetic nerves has been observed by others. Shingleton and co-workers [10] discarded electrical stimulation as a method of producing spasm of the sphincter of Oddi because of inconsistent results. Lueth [8] noted that vagal stimulation caused an increase in sphincter resistance in five dogs and a decrease in five. The mixed nature of the nerves themselves plus marked anatomical variations in the biliary tract probably account for these results.

It became apparent early in the present study that the sphincter of Oddi in the dog was extremely sensitive to variations in intraductal pressure. Hand injections had to be replaced by a constant injection device. Even with constant injection, too rapid a rate would produce a spasm of the sphincter and a rise in intraductal pressure from a basal pressure of 7 to 8 cm. of saline to 25 or 26 cm. of saline. Manometric control was necessary, and, in general, there was good correlation between the intraductal pressure and the state of contraction of the sphincter of Oddi.

While there appeared to be contraction of a papillary sphincter in response to splanchnic stimulation in four experiments, narrowing of this portion of the sphincter was present in some of the controls also and may have represented a tonic state of contraction compared with a completely relaxed sphincter. Intraductal pressures did rise, 7 and 13 cm. of saline, respectively, in two experiments with this narrowing and remained unchanged and fell 3 cm. in the other two.

Contraction and relaxation of the sphincter of Oddi in response to nerve stimulation did appear largely independent of the state of contraction of the duodenum. Franksson [6] has shown that choledochal nerves can be followed to the tip of the papilla with no direct communication between them and the nervous apparatus of the duodenal wall. It was difficult to be sure of the degree of contraction of the duodenum in some of the experiments in which it was not visualized when contrast media failed to pass the contracted sphincter of Oddi.

The strengths of the stimuli used in these experiments seem excessive when compared with those known to be effective in somatic nerve stimulation. The electrodes used were designed to give good contact with the nerves and to avoid shorting and spread to adjoining tissues insofar as possible. No effort was made to remove the nerve sheaths, however, and intact nerves were stimulated in contrast to peripheral stimulation of divided nerves. Stimuli of increasing strength were used until a level was found which produced a consistent effect. There was a suggestion of damage to the nerves in one animal eliminated from the series.

The present study is a preliminary investigation. Further refinement of the electrodes is in progress, together with efforts to determine minimal effective stimuli by monitoring the nerve in question at a distance with a cathode ray oscilloscope. Comparison of the effect of stimulating divided nerves peripherally is projected.

Summary

The effect on the sphincter of Oddi of electrical stimulation of the intact left vagus nerve below the diaphragm and the intact left splanchnic nerve proximal to the celiac ganglion was investigated in 10 dogs. Strong splanchnic stimulation with 10 to 20 volts caused contraction of the choledochal sphincter in two dogs, relaxation in two, apparent constriction of a papillary sphincter in four, and unsatisfactory observations in two. Weak vagal stimulation with 2 to 5 volts produced no effect in six dogs and an incomplete contraction of the choledochal sphincter in four. Strong vagal stimulation with 10 to 20 volts caused contraction of the choledochal sphincter in seven dogs, relaxation in two, and nonvisualization in one. Evidence was obtained for a bile duct sphincter in the dog which was under nervous control yet independent of contraction of the duodenal wall.

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The Diagnosis of Postcholecystectomy Biliary Tract Stones

A Comparison of Biliary Drainage and Intravenous Cholangiography

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When upper abdominal symptoms persist or recur after cholecystectomy, the possibility of stones being present in the common bile duct usually arises. Examination which will give positive evidence as to the presence or absence of such stones is obviously valuable. Both diagnostic transduodenal biliary drainage and intravenous cholangiography are of real help in this problem, but each has certain limitations. It is often necessary, therefore, to correlate data from both of these tests with the clinical evaluation of the patient before a reasonable decision can be reached regarding the advisability of surgery. Our experience with these two diagnostic examinations forms the basis of this report.

Diagnostic Transduodenal Biliary Drainage

To determine the diagnostic value of biliary drainage in detecting postcholecystectomy biliary lithiasis, we reviewed the records of all patients on whom exploration of the common bile duct was carried out from 1935 through 1955. Of this group of 580 patients, 61 met the four requirements for inclusion in this study. These four requirements were the following:

(1) Cholecystectomy carried out previously
(2) Complaint of recurrent upper abdominal pain with or without associated jaundice
(3) Satisfactory diagnostic biliary drainage carried out prior to subsequent surgery
(4) Subsequent exploration of the common bile duct carried out at our institution.

This group of 61 patients was then divided into five groups on the basis of the results of diagnostic biliary drainage correlated with findings at subsequent surgery. A positive biliary drainage examination indicates the finding of cholesterol crystals and/or calcium bilirubinate pigment in the bile, obtained via the tube which is passed beyond the pylorus. The five groups so

TABLE 1.—*Correlation of Diagnostic Biliary Drainage with Findings at Subsequent Surgery in Patients with Postcholecystectomy Symptoms*

Group	Findings	Patients No.
I	Positive biliary drainage—biliary stones at surgery	16
II	Positive biliary drainage—no stones at surgery but evidence of biliary stasis	2
III	Negative biliary drainage—stones at surgery	21
IV	Negative biliary drainage—biliary tract pathology other than stones at surgery	13
V	Negative biliary drainage—no biliary tract pathology at surgery	9
	Total number of patients	61

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segregated, along with the number of patients in each group, are shown in Table 1.

Of the 37 patients found to have biliary tract stones present at the time of subsequent surgery, 16, or approximately 45%, had positive diagnostic biliary drainage. It can also be seen that when biliary drainage is positive, stones of some size are actually present in all cases. On the other hand, a negative biliary drainage is not of decisive help, for approximately one-half of such patients were actually found to have stones in the biliary tract at subsequent surgery.

In Group I, the stone in one of the patients was actually found in the cystic duct remnant, and in another patient of this group the stone was present in a small gallbladder remnant. In Group III, the stone was actually present in a remnant of the gall bladder in one patient.

Although actual stones were not found in the biliary tract of the two patients in Category II at the time of surgery, pathologic abnormalities involving the biliary tract were found. Thus, we do not believe that these two examinations were actually false positive tests. In our experience one of the advantages of diagnostic biliary drainage is that it will also disclose evidence of the presence of microscopic stones and debris in the biliary tract which will not be disclosed by radiographic methods. It is also known that conditions producing stasis of bile will result in the finding of chunks of bile pigment but not cholesterol crystals on biliary drainage.

One of the patients of Group I was first seen with the problem of upper abdominal pain associated with jaundice. The biliary drainage was positive. The jaundice cleared, and surgery was delayed for a month. Flecks of debris were grossly visible at the time of surgery and a subsiding pancreatitis was noted, but no sizable stones were found. The second patient had a problem of right upper abdominal pain. Orange bile pigment was present in the biliary drainage. Surgery was undertaken two months later, but no stones were found in the bile ducts. However, there was chronic pancreatitis and a stenosis in the ampullary region was found and dilated.

The presence or absence of jaundice is important in making a decision as to whether patients having postcholecystectomy symptoms should be subjected to surgery again. Therefore, it is of interest to note the incidence of jaundice associated with the episode of pain in the various groups, especially Groups I and III. In Category I (positive biliary drainage, stones found), 11 of the 16 patients had a history of jaundice or jaundice was present at the time the patient was seen. In Category III (negative biliary drainage, stones found), only 10 of the 21 patients had been jaundiced. Thus, if the stones produce jaundice, it appears that biliary drainage is more likely to be positive. However, it is obvious that the presence of jaundice in postcholecystectomy patients does not necessarily indicate that stones are present. Of the 22 patients of Categories IV and V (negative biliary drainage, no stones at surgery), 5 did have a history of jaundice. Although the presence of jaundice is a factor favoring the necessity of further surgery in patients with abdominal pain after cholecystectomy, there are a number of causes for jaundice in such patients which do not necessitate surgery.

Repeated diagnostic biliary drainage examinations are of value at times. A single test was carried out in all patients of this series, except for nine patients on whom two examinations were carried out and one patient on whom three tests were done. Only the third test was positive in the patient given three examinations, and the patient did have common duct stones at the subsequent surgery. Of the nine patients on whom the test was repeated once, two had one negative and one positive test with stones being found in the common duct at later surgery. In three patients both examinations were negative, and yet stones were found in the common duct at subse-

quent surgery. In the remaining four of the eight patients, results of both tests were identical on each patient and were confirmed at subsequent surgery.

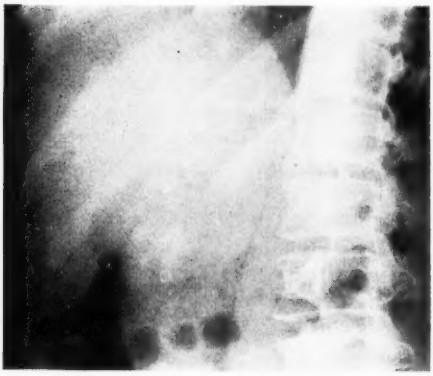
Intravenous Cholangiography

Intravenous cholangiography was carried out between August, 1954, and December, 1955, on 50 patients on whom a cholecystectomy had previously been performed and who were having upper abdominal symptoms. Sodium iodipamide (Cholografin) was used in these examinations. In 16 of these patients cholecystectomy had been carried out previously, and the extrahepatic biliary tract was explored subsequently at our institution. This group is too small to warrant major conclusions but does provide an experience for comparison with diagnostic biliary drainage. Of the 16 patients who subsequently underwent further surgery, 14 also had diagnostic biliary drainage preoperatively and are included in the group of 61 patients on whom diagnostic biliary drainage was evaluated (Figs. 1 and 2).

Of the group of 16 patients who underwent surgery, intravenous cholangiography was unsatisfactory for diagnostic purposes in 7 (mild jaundice in 2). Of nine patients in whom stones were found at subsequent surgery, intravenous cholangiography was technically inadequate for diagnosis in four, but evidence of obstruction to the common duct was shown in four (44%). The intravenous cholangiogram was interpreted as definitely abnormal in 7 of the 16 patients, and in 6 of these 7 patients an abnormality (stones in 3) requiring surgical correction was found. In two of the patients in whom an abnormality was corrected at surgery,

TABLE 2.—*Intravenous Cholangiography Correlated with Findings at Subsequent Surgery in Patients with Postcholecystectomy Symptoms*

Group	Patients, No.	
Patients who subsequently underwent surgery		16
Test unsatisfactory for diagnosis	7	
Positive test—confirmed at surgery	6	
Positive test—normal duct at surgery	1	
Negative test—stones removed at surgery	1	
Negative test—normal ducts at surgery	1	
Patients not operated on		34
Test unsatisfactory for diagnosis	4	
Biliary ducts normal	30	
Total number of patients		50



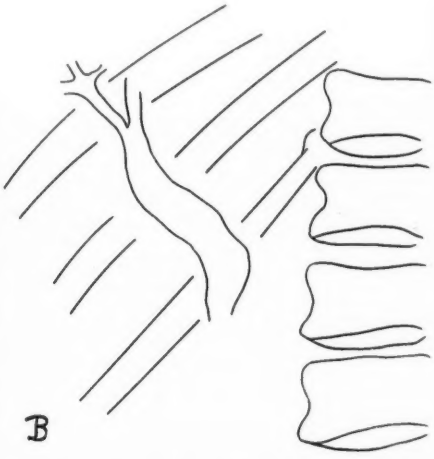


Fig. 1.—Intravenous cholangiogram showing 16 mm. common bile duct in patient having attacks of abdominal pain and pancreatitis after cholecystectomy. Biliary drainage negative. At surgery, fibrosis of sphincter of Oddi found but no stones present.

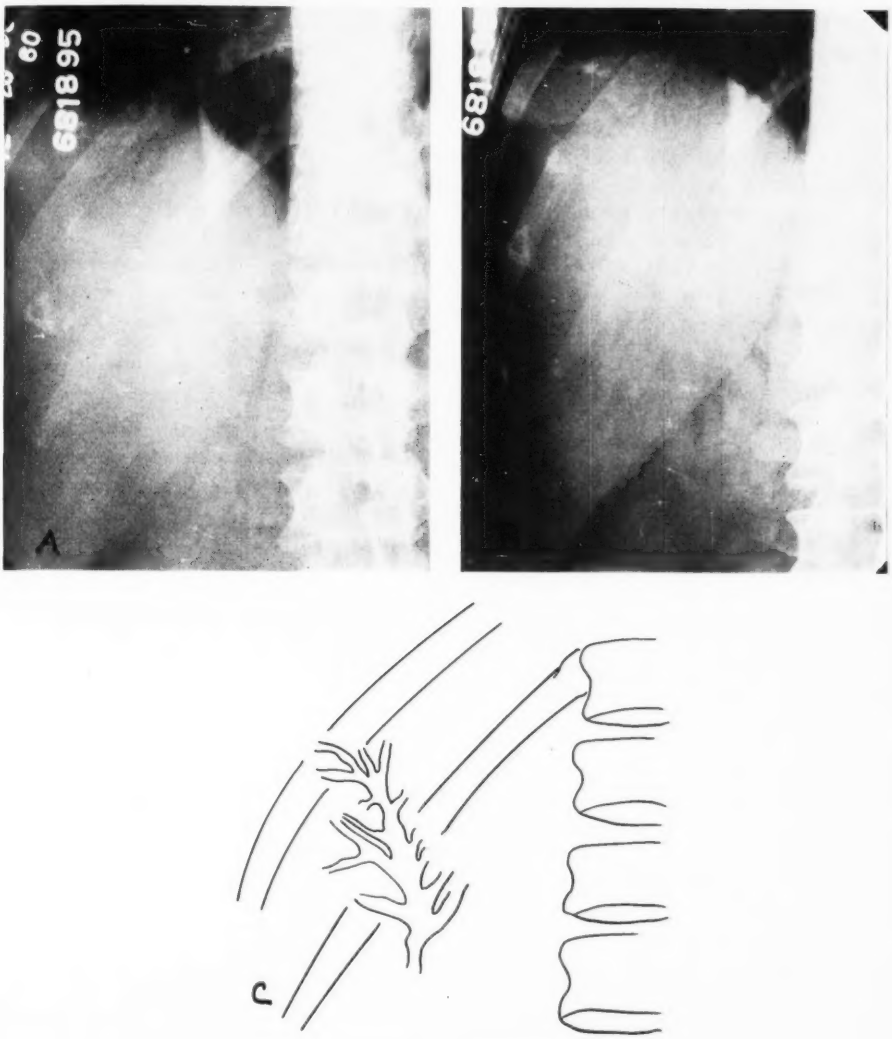


Fig. 2.—Intravenous cholangiograms in patient having attacks of biliary tract obstruction after cholecystectomy. Film *B* taken at 120 minutes shows dilated intrahepatic ducts more distinctly than film *A* taken at 60 minutes. Biliary drainage positive. Stones in hepatic ducts removed at surgery.

the surgery was based to a large degree on the findings of intravenous cholangiography. In one of the patients no abnormality of the biliary tract was found at surgery.

Of the nine patients found to have biliary tract stones at subsequent surgery, diagnostic biliary drainage had been carried out preoperatively in eight. Of these eight patients, biliary drainage was positive in three. In one of these patients, the intravenous cholangiogram was considered normal, but biliary drainage was positive.

Surgery was then carried out largely on the basis of the biliary drainage findings, and common duct stones along with a gall bladder remnant containing stones were removed at surgery.

In the 34 patients on whom intravenous cholangiography was carried out but on whom surgery was not performed, 4 of the tests were unsatisfactory for diagnostic purposes (mild jaundice in 2). In the remaining 30 patients, the examination was considered to show normal duct systems.

Comment

The cause of upper abdominal pain in the patient following cholecystectomy is often difficult to ascertain. Examinations which will show the presence of an abnormality in the biliary tract and thus indicate the necessity of surgery are of real help. Our experience shows that both diagnostic biliary drainage and intravenous cholangiography are of real aid in this problem.

Diagnostic biliary drainage has been available for many years. It was first described by Lyon in 1919.* It has been in use in our institution for 32 years.† When positive, this test gives nearly conclusive evidence that stones are present in the biliary ducts. In the past, others also have noted the definite value of biliary drainage in detecting postcholecystectomy common bile duct stones.‡

Mateer and associates[4] have demonstrated that biliary drainage is of particular value in jaundiced patients where radiographic methods are precluded. These authors found that in a group of patients with operatively proved common duct stones, whether or not the gall bladder was still present, either positive or highly suggestive biliary drainage evidence of stones was demonstrated in 54%.

Although intravenous cholangiography has come into clinical usage more recently, it is now established as a valuable aid in the evaluation of postcholecystectomy symptoms.§ Actually, in our limited experience, stones have been detected in the biliary ducts with about the same frequency by biliary drainage as with intravenous cholangiography. Certain refinements in technique have been evolved, such as the presence of greater density of the duct system at 120 minutes over that at 60 minutes indicating partial obstruction. This and other modifications in technique will undoubtedly increase the accuracy of the test.‖ Intravenous cholangiography is more versatile than biliary drainage in detecting abnormalities in the biliary ducts, yet each has distinct advantages and distinct limitations (Tables 3, 4, 5, and 6). Each test is of value, and one does not supplant the other. The value of each test is increased when carried out by persons specifically interested in it.

Although these examinations are of real help, the careful and sound clinical evaluation of the patient will continue to be the most important factor in the diagnosis and treatment of the patient with upper abdominal symptoms following cholecystectomy.

Summary and Conclusions

Diagnostic transduodenal biliary drainage will give positive evidence of postcholecystectomy biliary lithiasis in about one-half of the cases in which stones are actually present. A positive test is definite evidence that stones exist, but a negative test is not significant clinically.

The presence of significant abnormalities in the extrahepatic biliary tract shown by intravenous cholangiograms is usually confirmed at subsequent surgery. The value of this examination is limited in that it is not satisfactory for diagnostic purposes in a number of patients with postcholecystectomy symptoms.

Both diagnostic transduodenal biliary drainage and intravenous cholangiography are of real value in the evaluation of the problem patient with postcholecystectomy

* References 1 and 2.
† References 3 and 4.
‡ References 5 and 6.
§ References 7 through 11.
‖ References 8 through 10.

TABLE 3.—*Advantages of Diagnostic Biliary Drainage*

1	Can be done in presence of jaundice and decreased liver function
2	Will indicate presence of stones specifically as cause of difficulty in postcholecystectomy symptoms
3	May diagnose other pathologic conditions such as microscopic stones or parasites

TABLE 4.—*Disadvantages of Diagnostic Biliary Drainage*

1	Requires special technique and experience
2	Negative test has no significance
3	Duodenum cannot be intubated if gastrojejunostomy has been previously performed
4	Will not visualize biliary tree and will not indicate anatomic abnormalities

TABLE 5.—*Advantages of Intravenous Cholangiography*

1	Relatively simple to perform
2	By visualizing biliary tree, obstruction from any cause can be demonstrated
3	Will show presence of cystic duct remnant or gallbladder remnant

TABLE 6.—*Disadvantages of Intravenous Cholangiography*

1	Frequently unsatisfactory for diagnostic purposes in presence of jaundice or poor liver function
2	Frequent borderline tests—caliber of common duct varies widely within normal limits
3	Sensitivity of some patients to sodium iodipamide
4	May not indicate presence of stones in common bile duct as the actual cause of the obstruction
5	Does not well visualize terminal duct
6	Can have normal test despite presence of tiny stones in common bile duct

symptoms. Both have distinct advantages and also limitations. The two tests are complementary, and each has an important place in diagnosis.

These tests are only aids and are to be used to supplement the sound clinical evaluation of the patient with postcholecystectomy symptoms.

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DISCUSSION

ON PAPERS BY DRS. PARTINGTON, JONES, AND JOHNSON; AND BLOCK, BRUSH, PONKA, AND PRIEST

DR. LOUIS T. PALUMBO, Des Moines: I would like to take the opportunity to compliment Dr. Partington on his excellent study.

Our experience with autonomic nervous system surgery during the past 18 years has shown that a great many variations in the innervation and distribution may occur, particularly in certain areas of the body. There is some evidence of cross innervation and overlapping of the nerve supply; also, in many specific areas primary major pathways controlling specific functions exist. However, there are also secondary pathways which are capable of taking over the primary function when the primary pathway is destroyed or ablated.

Because of these possibilities in the human, I am sure Dr. Partington will, in his future studies of the sphincteric mechanism, stimulate the right splanchnic nerve and also perform a simultaneous stimulation of the right and left splanchnic nerves.

I might suggest, too, that stimulation bilaterally of the lower dorsal and upper lumbar sympathetic chains be tried to determine what part, if any, these may play in the innervation of the lower common bile duct, sphincter of Oddi, and the pancreatic ducts.

DR. PHILIP F. PARTINGTON, Cleveland: I asked Dr. Boyden to discuss this paper, not realizing that he was at the University of Washington at present, but Dr. Boyden was kind enough to send a drawing of his reconstruction of the sphincter in the dog on the basis of his reconstructions from serial sections.

The thing that has interested me greatly is that this drawing can practically be superimposed on the sphincter region of the control cholangiogram in the dog without stimulation.

We believed that the anatomic studies had gone about as far as they could in showing what went on in this region, and for that reason we wished to try a more physiological method of investigating it.

DR. B. E. BRUSH, Detroit: The point which we wish to bring out in this paper is that when some new method comes along, usually all older methods are discarded. We believe that biliary drainage still is of great help in some of these patients. In several of them the intravenous cholangiography was unsatisfactory—at least it was not diagnostic, whereas the biliary drainage was. When positive findings are obtained on biliary drainage, the diagnosis of stones is definite and final. It is the negative tests in each of these studies which leave the issue undecided. However, the application of sound clinical judgment and these two tests will result in a high degree of diagnostic accuracy.

Experimental Chronic Pancreatitis

CHARLES N. FLOYD, M.D.
and
WILLIAM M. CHRISTOPHERSEN, M.D.,
Louisville, Ky.

Claude Bernard just 100 years ago began the scientific study of pancreatitis by injecting bile and olive oil into the duct.* Since then many able investigators have attacked the problem with a variety of methods and ideas, producing acute pancreatitis without difficulty. Since this paper deals primarily with the chronic phase of the disease, no attempt will be made to review the work on acute pancreatitis. Good discussions may be found in the publications of Opie, 1901 [2]; Archibald, 1919 †; Gage and Floyd, 1947 [5]; Doubilet and Mulholland, 1948 [6]; Floyd and Van Meter, 1951 [7]; and, more recently, Sensenig and Bowers [8] and Whitrock, Hine, Crane, and McCorkle.[9]

Chronic pancreatitis, perhaps an even more baffling clinical problem, has not been consistently produced in experimental animals. In a careful review of the literature we were not able to find work directed toward a satisfactory method for creating chronic pancreatitis. There is increasing evidence that ductal obstruction, from whatever cause, is a major factor in this disease. The fact that simple ductal ligation produces atrophy without ductal dilatation led us consider the possibility that gradual ductal occlusion might be more successful in producing more typical, experimental chronic pancreatitis.

Submitted for publication April 3, 1956.

From the Departments of Surgery and Pathology, University of Louisville School of Medicine.

Read at the Thirteenth Annual Meeting of the Central Surgical Association, Rochester, Minn., Feb. 25, 1956.

* Bernard, cited by Opie.[1]

† References 3 and 4.

Historical Review

In 1884, Villiard and Amazon ‡ tied the pancreatic duct in an effort to create diabetes and noted a fibrotic shrinkage of the gland. Since then it has been shown many times that ligation with total obstruction to pancreatic drainage results in acinar atrophy and fibrosis after 7 to 10 weeks, with preservation of the islet cells.§ Opie's now famous autopsy observation, in 1901, was an early indictment of obstruction as an etiological factor.[2] In 1909, Coffey, in an experimental study, reported what seems to be the first retrograde drainage of pancreatic secretion into the intestinal tract, utilizing the normal structures in a dog. He noted chronic pancreatitis with dilated ducts in two dogs following this procedure.[14]

In 1917, Patrie, Pyle, and Vale showed experimentally that pancreatointestinal anastomosis, with maintenance of function, can be successfully accomplished by inserting any desired portion of the pancreatic duct of the dog through the intestinal wall and suturing the surrounding cut edge of the pancreas to the serosal surface of the intestine.[15] Their experiments included caudal anastomosis of this type, a procedure which has more recently been proposed as a treatment for human pancreatitis.

In 1934, Tripodi and Sherwin showed experimentally that the pancreas could be drained into the stomach.[16] In 1946, Comfort, Gambill, and Baggenstoss presented a very excellent study of chronic relapsing pancreatitis.[17] Cattell and Warren discussed this problem and emphasized their belief that obstruction is an important etiologic factor in this disease.[18] Edmondson, Bullock, and Mehl in 1949 reported the pathologic aspects of chronic pancreatitis and

‡ Villiard and Amazon, cited by Banting.[10]

§ References 11, 12, and 13.

lithiasis in 62 cases; they found ductal dilatation to be common.[19] Recently, Berens, Baggenstoss, and Gray presented an excellent study of ductal changes in chronic pancreatitis and suggested, as have others, operative retrograde drainage of the pancreas.[20] Leger in 1953 reported transduodenal "Wirsungography" to determine at the operating table the presence or absence of ductal dilatation.[21] More recently, Sensening and Bowers showed that caudal pancreaticojejunostomy can be established in dogs, and that animals so treated do not develop pancreatitis following intraductal injection of bile at pressures causing acinar rupture.[8] Bonta carried out an interesting series of experiments on pancreaticojejunostomy and showed that anastomosis to a jejunal loop apparently works as well as one carried out by the Roux-Y technique. His work also showed that if the ductal obstruction is relieved, the pancreaticojejunostomy usually ceases to function.[22] This procedure has recently been proposed as a treatment for human pancreatitis with dilated ducts.‖

In casting about for a method to produce slowly progressive occlusion of the pancreatic duct, we became interested in the work of Berman.¶ During a visit to his laboratory he presented us with two methods to produce gradual occlusion of a tubular structure.# We used these methods with slight modifications; one was unsuitable, the other very successful.

Material and Methods

Healthy selected mongrel dogs varying in weight from 15 kg. to 25 kg. were used. They were fed regular canned rations and dewormed if necessary. Intravenous sodium pentobarbital (Nembutal), 30 mg. per kilogram of body weight, was used for anesthesia. Operations were done through midline incisions, which were closed with interrupted #40 cotton sutures. The animals received 300,000 units of penicillin daily for five days and were allowed water and food as desired.

The anatomy of the dog's pancreas differs somewhat from the more familiar human counterpart, as demonstrated in Figure 1. In the dog the major pancreatic duct serves the head, body, and tail, draining separately into the duodenum 2 cm. distal to the combined papilla, which contains the common bile duct and the minor pancreatic duct. The minor duct drains the inferior process and is a constant structure. There is commonly a communication between these two pancreatic ducts; however, it is not adequate for drainage of the total secretion of the gland. Minimal dissection

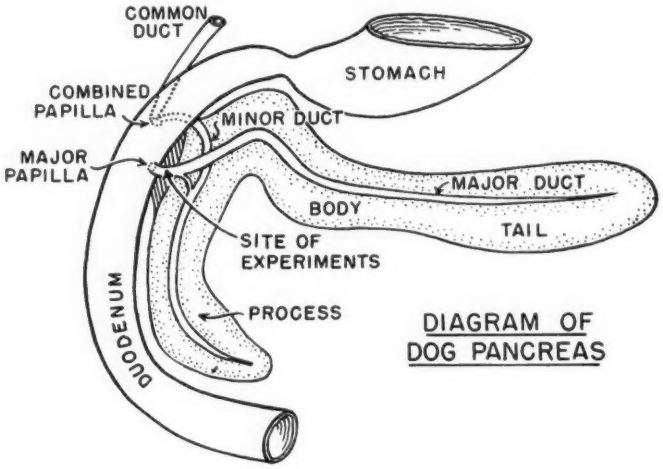

Fig. 1.—Diagram of the dog pancreas.

‖ References 20, 23, and 24.

¶ References 25 and 26.

Berman, J. K.: Personal communication to the authors.

is required to expose a 5 mm. segment of the major duct at its entrance into the duodenum.

The animals were divided into three groups:

Group A.—*Attempted Ductal Obstruction by Ameroid Plastic "Buttons"* (six dogs).—Brown Ameroid was obtained in a rod form, measuring 0.485 in. in diameter. "Buttons" were cut 0.15 in. thick at an angle of 55 degrees. An offset hole was drilled, varying from 0.109 to 0.114 in. in diameter to suit the duct size. A 0.06 in. slot was cut to provide a method of encircling the duct. Accurate hemostasis was obtained with electrocautery and cotton ligatures. The Ameroid collar was secured by a stainless steel wire and the area peritonealized (Fig. 2).

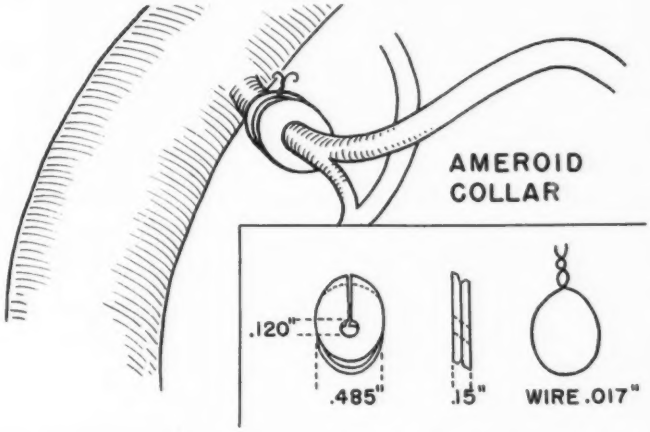

Fig. 2.—Diagram illustrating the Ameroid collar and its placement, the procedure used for Group A animals.

Ameroid plastic was used because of its ability to slowly absorb tissue fluids. Maximal swelling occurred in six to eight weeks and was directed inward by the constraining metal wire.

Group B.—*Attempted Ductal Obstruction by Dicetyl Phosphate Infiltration* (three dogs).—The major pancreatic duct was exposed as in Group A and treated with sodium dicetyl phosphate, which was injected intramurally with a No. 26-gauge needle until blanching of the duct wall occurred. The injection encircled the duct just proximal to its entrance into the duodenal wall, after which the area was peritonealized (Fig. 3).

Sodium dicetyl phosphate* in a 2% aqueous solution was prepared by autoclaving, allowing a slow return to normal pressure. This was necessary to prevent foaming and resulted in a milky colloid-like solution, which was easy to handle.

Group C.—*Attempted Ductal Obstruction by Dicetyl Phosphate Infiltration with a Plastic Col-*

* Sodium dicetyl phosphate, H & M Chemical Co., Ltd., Santa Monica, Calif.

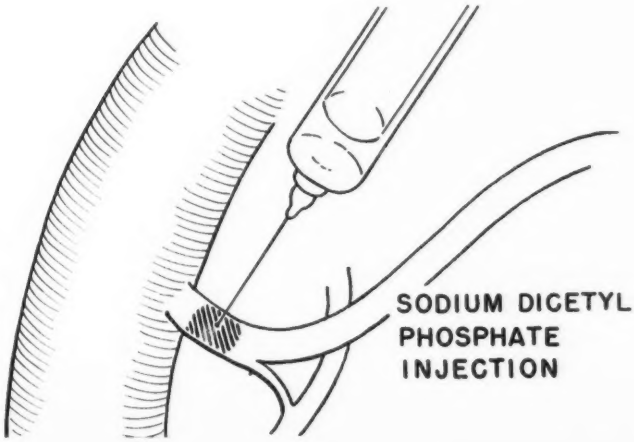

Fig. 3.—Site of injection of sodium dicetyl phosphate in Group B animals.

lar.—The major pancreatic duct was exposed and injected with sodium dicetyl phosphate as in Group B, and a snug-fitting polyethylene collar was applied and secured with a single cotton tie (Fig. 4). The area was peritonealized.

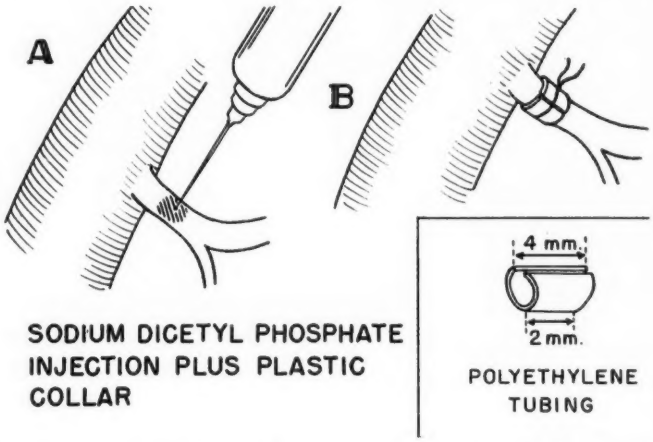

Fig. 4.—Combination of sodium dicetyl phosphate injection plus the polyethylene tubing used in Group C dogs.

The polyethylene plastic collar † was constructed from disposable intravenous tubing. It was occasionally necessary to adjust the inner diameter to a snug fit over the pancreatic duct. The basic principle in mind was to constrain the fibroblastic activity of the sodium dicetyl phosphate to produce a slowly progressive, compressive obstruction.

Results

Only one of the six dogs in Group A developed chronic pancreatitis with dilated ducts (Table 1). The other five animals remained clinically well. At autopsy the Ameroid button was found to have eroded through the ducts in all five animals. The area of erosion was surrounded by a cavity containing all or a portion of the button and the wire. When India ink was injected into the pancreatic duct near the tail of the organ, there was free flow of the dye through this cavity into the duodenum. The remainder of the pancreas remained normal. The single dog with chronic pancreatitis showed partial occlusion of the duct at the site of the button. The gland was enlarged, white, and very firm. The lobular markings were accentuated. The main duct was markedly dilated and contained milky material and debris. There were areas of pancreatic saponification along the main body of the

† Polyethylene Plastic I. V. tube, Fenwal, Macalaster Bicknell Parenteral Corp., Cambridge, Mass.

TABLE 1.—*Group A Experiments*

Exp. No.	First Wt., Kg.	Final Wt., Kg.	Total Days of Exp.	Cause of Death	Gross Impression	Micro. Impression	Ducts Dilated	Collar Eroded Duct	Amylase
19	14.7	14.5	114	Killed	Normal	..	No	Yes	..
20	10.0	8.2	15	Distemper	Normal	..	No	Yes	..
21	18.8	20.5	147	Killed	Normal	..	No	Yes	..
23	9.9	8.6	8	Distemper	Normal	..	No	Yes	..
24	15.0	14.1	91	Killed	Chronic pancreatitis, mod. severe	Chronic pancreatitis, mod. severe	Mod.	No	..
29	16.4	15	105	Killed	Normal	..	No	Yes	..

TABLE 2.—*Group B Experiments*

Exp. No.	First Wt., Kg.	Final Wt., Kg.	Total Days of Exp.	Cause of Death	Gross Impression	Micro. Impression	Ducts Dilated	Collar Eroded Duct	Amylase
9	17.7	19.1	90	Killed	Normal	..	No	..	..
14	14.1	12.8	97	Killed	Normal	..	No	..	..
28	14.5	15.5	118	Killed	Normal	Normal	No	..	..

gland and in the omental fat. The untreated accessory duct appeared normal, as did that portion of the pancreas drained by this duct. Histological examination of the involved pancreas showed minor atrophy and fibrosis with marked lymphocytic infiltration, most marked in the perilobular areas. The ducts were dilated, and the epithelium compressed and partially destroyed. There was marked periductal lymphocytic infiltration. The inferior process of the gland was histologically normal.

All dogs in Group B remained well from 90 to 118 days (Table 2). At autopsy there were no significant gross or histological changes in the pancreas.

Group C showed the most impressive changes (Table 3). Two of these animals died of distemper on the 13th and the 25th day before sufficient time had elapsed for ductal obstruction to develop; they gave no evidence of pancreatitis. One died of distemper on the 37th day and showed microscopic evidence of pancreatitis. The collar had eroded the duct completely in this animal, but flow of pancreatic secretion into the duodenum was maintained through a small walled-off cavity.

TABLE 3.—*Group C Experiments*

Exp. No.	Oper. Wt., Kg.	Final Wt., Kg.	Total Days of Exp.	Collar Eroded Duct	Gross Impression	Micro. Impression	Amylase	Cause of Death	Ducts Dilated
12	18.2	18.1	127	Yes	Normal	Normal	..	Killed	No
13	22.3	22.3	63	Yes	Normal	Mild pancreatitis	..	Killed	No
15	20	13.6	79	No	Severe pancreatitis	Severe pancreatitis	1,440	Killed	Marked
16	13.6	8.4	37	No	Normal	Mild pancreatitis	2,500	Distemper	Mild
17	25.3	16.9	25	No	Normal	Normal	1,250	Distemper	No
18	12.3	10	13	Yes	Normal	Normal	1,440	Distemper	No
22	12.3	12.5	136	No	Moderate pancreatitis	Severe atrophy	..	Killed	Mod.
25	13	9.9	69	Yes	Severe atrophy	Severe atrophy	10,320 1,280	Killed	Marked
26	17	17	123	No	Moderate pancreatitis	Moderate pancreatitis	..	Killed	Mod.
27	19	17.4	82	No	Moderate pancreatitis	Minimal pancreatitis	..	Killed	Mod.
33	15.5	14.5	72	Yes	Mod. severe pancreatitis	Mod. severe pancreatitis	..	Killed	Mod.

Seven of these dogs developed chronic fibrosing interstitial pancreatitis with dilated ducts. Two had erosion of the major duct but still developed severe disease. (The recanalization in these cases may have been a later development.) One animal had an episode of acute pancreatitis diagnosed by elevated serum amylase, which returned to normal in seven days. The others manifested an insidious onset of disease usually with weight loss, anorexia, and diarrhea, which consisted of semiliquid feces grossly resembling the canned ration. The dogs had periods of irritability with their kennelmates lasting several days.

In all, 8 of the 11 animals developed some degree of chronic pancreatitis. The pancreas was usually enlarged in the mild form of the disease and was small, firm, nodular, and white in the more advanced cases. It cut with increased resistance and was obviously fibrotic. The major duct was always dilated in the advanced stage of the disease and contained milky-white liquid and debris. The portion of the gland drained by the untreated ducts was uniformly normal in appearance.

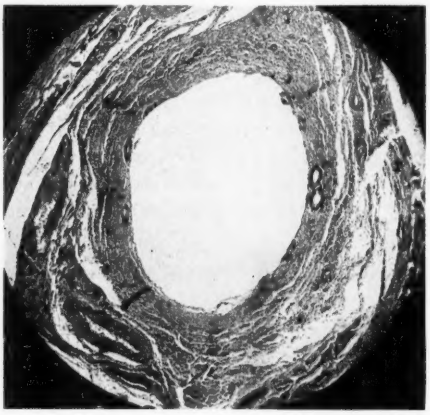

Fig. 5.—Duct dilatation present 72 days following injection of sodium dicetyl phosphate and placement of polyethylene tubing around pancreatic duct.

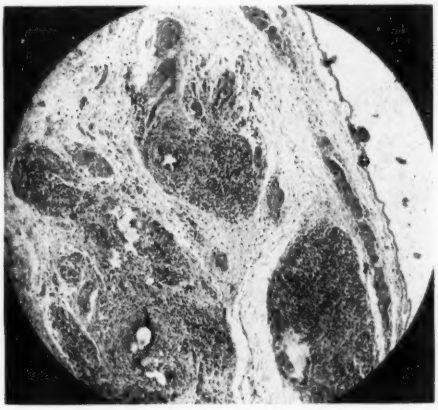

Fig. 6.—Fibrosis, atrophy, and inflammatory infiltrate. Group C, 69 days.

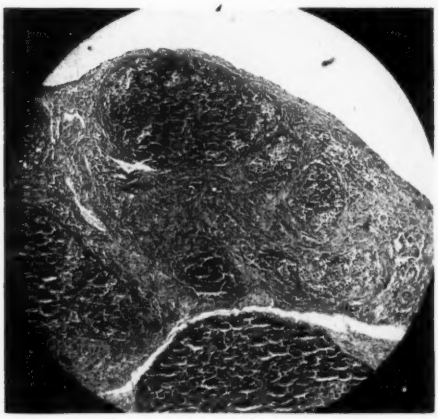

Fig. 7.—Chronic pancreatitis showing marked fibrosis.

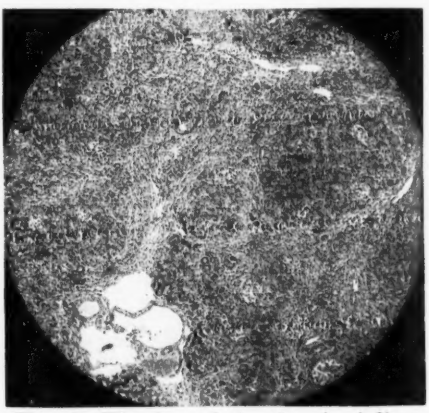

Fig. 8.—Fibrosis and lymphocytic infiltrate with moderate acinar atrophy are shown 123 days after Group C treatment.

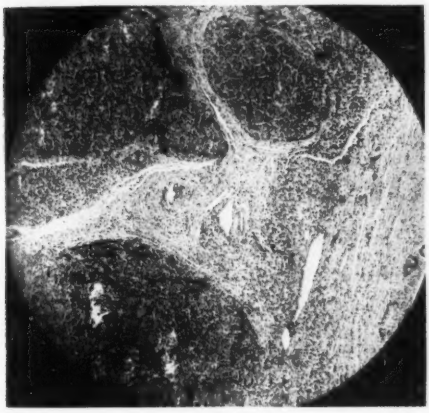

Fig. 9.—Group C dog, 79 days. Perilobular fibrosis and inflammatory infiltrate are seen; considerable acinar tissue remains.

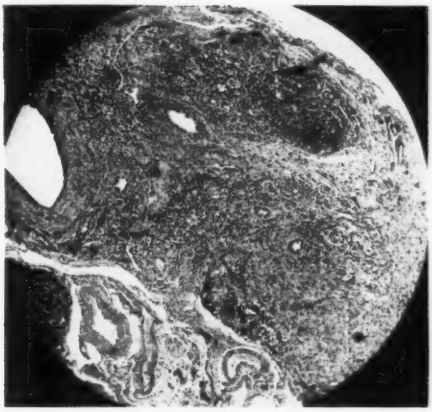

Fig. 10.—Same dog as in Figure 9. Periacinar inflammation and fibrosis are evident.

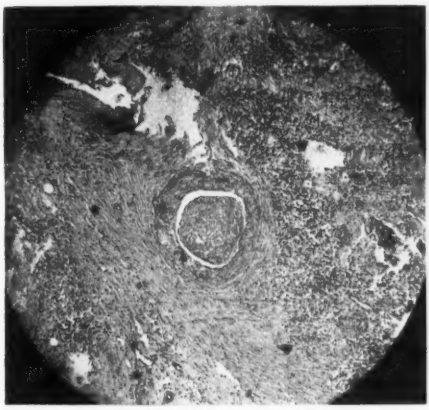

Fig. 11.—Acute inflammation and vascular thrombosis near injection site 13 days after injection of sodium dicetyl phosphate.

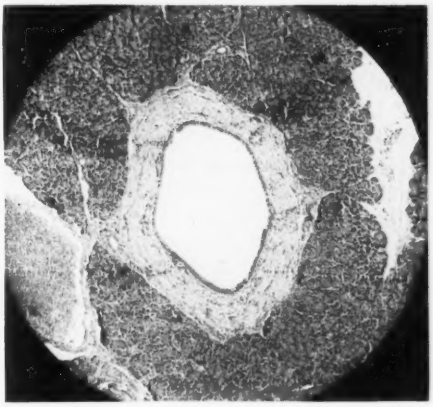

Fig. 12.—Section through inferior process showing normal pancreas.

The histological changes were qualitatively the same but differed quantitatively from animal to animal. Ductal dilatation was uniformly present, and the epithelial lining was often partially or completely destroyed (Fig. 5). (Contrast this with normal dog pancreas, Fig. 12.) There was chronic inflammatory infiltrate in the duct wall and the periductal tissues (Fig. 6). The acini showed varying degrees of atrophy (Figs. 7 and 8). Perilobular fibrosis and inflammation were always evident and usually marked (Fig. 9). Periacinar fibrosis and inflammation were present but never as marked as in the perilobular areas (Fig. 10). Acute inflammation was never impressive except at the injection site, where vascular thrombosis and occasionally necrosis were encountered (Fig. 11). The inferior pancreatic process, drained by the accessory duct, remained unaltered in all cases (Fig. 12).

Comment

There is good evidence that obstruction of the pancreatic ducts is of paramount importance in the causation of chronic pancreatitis of the type produced in these ex-

perimental animals. It would also seem reasonable that this obstruction must be gradual over a prolonged period of time. The major difference between simple ligation and gradual occlusion is the lack of ductal dilatation with simple ligation. In other words, simple ligation merely produces acinar atrophy and fibrosis of the gland, while gradual occlusion caused ductal dilatation and chronic pancreatitis in these animals. Other factors may be involved in this chronic interstitial pancreatitis with ductal dilatation, but they were not evident in these experiments.

The role played by the surgical manipulation of the pancreas in these animals can readily be evaluated, since Groups A and B serve as control animals in this respect. The animals of these two groups had the same manipulation of the pancreas as Group C; yet only one of the nine animals in Groups A and B showed any pancreatitis, and even in this one the changes were moderate in degree. In this animal there was evidence that long-standing partial obstruction had occurred before the Ameroid button finally eroded through the duct. By contrast, 8 of 11 of the dogs in Group C developed typical pancreatitis with ductal dilatation. (Actually, eight of the nine who lived long enough for gradual ductal occlusion to occur developed chronic pancreatitis.)

Clinical observation of the animals from the time of operation to autopsy often showed evidence of repeated episodes of mild pancreatitis during which the dogs refused food, lost weight, became irritable, often withdrew from the group, and had frequent semiliquid stools. Unfortunately, it was not possible to follow the animals with routine serum amylase determinations. One animal who did have amylase determinations showed a tenfold increase during a symptomatic stage. This returned to normal within one week.

The progress of the disease and the end-result produced in these animals simulated the course of the disease in humans closely enough to suggest that this process is quite similar to the chronic pancreatitis seen in man. The procedure herein outlined is, therefore, offered as a tool for the production of a comparable disease in an easily available laboratory animal. It is hoped that its use may aid in studying the disease process itself and in evaluating methods proposed for its treatment.

Summary and Conclusions

Ameroid plastic collars placed around the major pancreatic duct of dogs usually eroded through the ducts and so failed to produce consistently either ductal obstruction or chronic pancreatitis.

Simple injection of a fibroblastic agent, sodium dicetyl phosphate, into the wall of the major pancreatic duct of the dog failed to produce chronic pancreatitis.

Chronic interstitial pancreatitis with ductal dilation was consistently produced in dogs by injecting the wall of the major pancreatic duct with sodium dicetyl phosphate and placing a polyethylene collar about the site of injection.

The pathologic process produced by this method appears sufficiently comparable to that seen in man to justify the use of this technique as an approach to the experimental study of pancreatitis.

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Postoperative Pancreatitis

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Acute pancreatitis occurring as a postoperative phenomenon is a serious and often disastrous complication. Most commonly it follows biliary tract or gastric operations, but occasionally it occurs after splenectomy, and in rare instances after operations in which there has been no possibility of direct injury to the pancreas or interference with its blood supply. Although relatively infrequent, it has been an important factor in the mortality of biliary tract and gastroduodenal surgery. Unfortunately there is no clear understanding of the pathogenesis of pancreatitis in this form. It is possible that a different mechanism or a combination of more than one are responsible under varying situations. Thirty such cases have been diagnosed on the surgical service of the Ohio State University Hospital, and these will be reviewed from the standpoint of clinical features, pathogenesis, and mortality.

Diagnosis

The diagnosis in all cases has been made on the basis of significant elevations of the serum amylase values or operative or postmortem findings. The classical manifestations of the disease are often masked by the postoperative state, and such signs as abdominal pain, ileus, and shock are not specific and hence must be interpreted carefully. The serum amylase determination is often helpful only in the first two or three postoperative days, since in many instances of pancreatitis this level returns to normal within such a period. A mild elevation of the amylase value without other evidence does not necessarily imply pancreatitis, and the diagnosis is probably not justified on this basis alone.

When the process is severe, the development of a serious intra-abdominal complication is obvious, though the exact diagnosis may not be apparent unless pancreatitis is suspected and an elevated serum amylase level is found. Persistent ileus with distention is common. Vomiting may occur if gastric suction has been discontinued. Failure to pass flatus or stool per rectum may be noted, or, paradoxically, there may be diarrhea. Severe abdominal pain has not been prominent in all cases, though moderate distress is usual and back pain is an occasional complaint. The patient may be more comfortable lying on his side with his back flexed and his knees drawn up. On examination a soft distention is a frequent finding. Tenderness in the upper abdomen of some degree is elicited, but often is not striking and may shift from day to day. The development of a palpable upper abdominal mass and icterus are signs which become apparent in some cases. Shock and renal shutdown are not infrequent in severe cases and indicate a most unfavorable prognosis.

Laboratory data other than the amylase value are seldom of help in the differential diagnosis. In severe forms of pancreatitis a marked leucocytosis is usual, and in one of our cases the white blood cell count exceeded 50,000 per cubic millimeter. With massive necrosis, diabetes may develop. A low serum calcium level several days following the onset of severe pancreatitis may be seen, and Edmondson and Berne have stressed the grave prognostic significance of a serum calcium level below 7 mg. per 100 cc.[1]

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Roentgenologic studies may suggest the diagnosis, though in the severely ill patients, in whom the information would be most welcome, there is little inclination to perform more than the simplest examinations. Films of the abdomen demonstrate the ileus and possibly the presence of intraperitoneal fluid. Study of the upper gastrointestinal tract with barium may indicate the presence of a retroperitoneal mass with forward displacement of the stomach and may also show widening of the curve (C-loop) of the duodenum.

Associated Complications

Difficulties in diagnosis and treatment were increased by the large number of associated complications. In approximately two-thirds of the cases there were significant postoperative complications other than pancreatitis, and one misfortune after another beset a few of these patients until death supervened (Table 1). In these complex cases the precise significance of the pancreatitis in the patients' morbidity and mortality is sometimes impossible to assess.

TABLE 1.—*Frequency and Variety of Postoperative Complications Other Than Pancreatitis (Nineteen of Thirty Cases)*

	Cases, No.
Pulmonary	10
Renal	8
Wound	3
Cardiac	5

Pulmonary and renal complications were the most frequently encountered. Atelectasis accounted for most of the pulmonary difficulties, though in one instance aspiration of vomitus occurred and was probably the immediate cause of death. Oliguria or anuria with consequent azotemia developed in eight patients. This renal failure apparently was a secondary phenomenon to shock in these patients. There were three wound complications including two eviscerations. Disturbances in cardiac rhythm were diagnosed in five cases. It is apparent that these complications did not develop as isolated events, but were interrelated in many instances.

Following Bilary Tract Surgery

Ultimately it may be proved that there is essentially a simple cause of pancreatic inflammation and necrosis occurring after surgery, and that hence there is little logic in dividing the discussion under headings of the various antecedent surgical procedures. However, with our present limited knowledge of the basic factors in the pathogenesis of the disease, it is convenient and reasonable to consider the complication in relation to the commoner operations with which it is associated.

Thirteen of the present series followed biliary tract operations. In all of these, exploration of the common bile duct was a part of the procedure, though in only three cases were common duct calculi recovered. In 10 cholecystectomy was performed, and in 1 a cholecystojejunostomy was done. In the other two, the gall bladder had previously been removed, and the common duct was explored as a secondary procedure. In three cases a duodenotomy and retrograde exploration of the common duct were added to the conventional method of exploration, and a sphincterotomy was done in one of these. It is of interest that in one of the latter cases in which a sphincterotomy was not done, a long T-tube with one end drawn through the ampulla of Vater into the duodenum was used.

There were six deaths in this group, a mortality of almost 50%. At postmortem examination the degree of pancreatitis was severe in four of the six, with marked pancreatic necrosis and hemorrhage, so that the cause of death in these four seems definitely to be the pancreatitis. In one of the remaining cases the pancreatitis was of only moderate severity, and there were wound and pulmonary complications as well as renal changes characteristic of lower nephron nephrosis. In the final case autopsy was not performed.

The clinical features of pancreatitis fol-

lowing operations on the biliary tract are best appreciated by the presentation of illustrative case reports.

CASE 1.—A 40-year-old man was hospitalized with a presumptive diagnosis of gallstones on the basis of history and a nonfunctioning gall bladder. Jaundice was suspected but not proved definitely one month earlier. Cholecystectomy and common bile duct exploration were performed on the third hospital day. There were multiple small stones in the gall bladder but none in the common duct. The procedure was technically straightforward; the common duct exploration was performed in a routine manner, and woven silk catheters up to No. 16 F. were passed through the ampulla of Vater.

Postoperatively there was persistent ileus with moderate distention, and the patient complained of epigastric and back pain. His course was febrile, and the leucocyte count reached 41,000 per cubic millimeter on the eighth postoperative day. Serum amylase determination was not done until the fifth day following surgery, at which time it was 11 units (Somogyi method). Subsequent determinations were comparably low. Serum calcium fell to 8.3 mg. per 100 cc. A persistent tachycardia was observed, and the electrocardiograph showed low voltage.

Roentgenologic studies demonstrated a raised left diaphragm, a left pleural effusion, and an ileus of the paralytic type. During the fourth week an epigastric mass accompanied by localized tenderness was interpreted as a subhepatic or pancreatic abscess. Reexploration showed extensive pancreatic necrosis. He died 30 days after the original operation, and at autopsy there was almost complete necrosis of the pancreas and a heavily walled-off abscess in the operative area. There was also extensive fat necrosis in the peritoneal cavity, the retroperitoneal area, the pericardium, and the bone marrow.

This case is in many respects classical of severe postoperative pancreatitis. The inflammatory process progressed to extreme necrosis with almost total dissolution of the pancreas and to suppuration. Clinically characteristic are the epigastric and back pain; the anorexia, nausea, and vomiting; the ileus and distention; the pleural effusion, and the roentgenologic findings. The very low amylase values are understandable in light of the destructive process.

CASE 2.—A 73-year-old white woman was admitted for evaluation of a previously discovered prepyloric mass. In addition, she had been hospitalized on three previous occasions and the diagnosis of gallstones established. Approximately two months prior to the current admission, because of severe anemia, an upper gastrointestinal series was done and a prepyloric tumor discovered.

After investigative and preparatory measures, operation was performed on the 10th postoperative day, and a polypoid lesion was found on the posterior wall of the stomach. This had the appearance of a gastric polyp and was excised. The gall bladder was small and fibrotic and contained a large calculus. Exploration of the common duct was negative. The patient's postoperative course was uncomplicated until the eighth postoperative day, at which time a cholangiogram was performed and a questionable defect in the lower end of the common duct discovered. A repeat cholangiogram on the following day was normal. The common duct catheter was then removed. The patient had a chill, a spike in temperature, and became acutely ill a few hours later with severe abdominal pain accompanied by tenderness in the upper abdomen. On conservative therapy her symptoms gradually improved over the course of the next three days.

On the 16th postoperative day, however, the patient again developed acute abdominal symptoms with pain, tenderness, distention, and vomiting. Serum amylase determination at this time was 2274 units. Again, on conservative therapy the pancreatitis gradually subsided and the amylase dropped down to near normal limits over the course of the next five days. However, on the 23rd postoperative day the patient again had an acute episode. This time the amylase rose to above 2000 units, returning to normal in approximately six days. During these episodes the patient developed a very minimal jaundice. Following this she gradually improved without further attacks.

The severe, though fortunately nonfatal, pancreatitis developing in this patient was probably initiated by the cholangiographic studies. A rise in serum amylase following cholangiography, if reflux of the dye into the main pancreatic duct occurs, has been well documented by the studies of Howell and Bergh.[2] In most instances such an elevation is minor, transient, and unaccompanied by clinical evidence of pancreatitis. That pancreatitis resulting from such a mechanism may be very serious is attested by the recent report of Hershey and Hillman of a patient in whom a fatal pancreatitis evidently resulted from an operative cholangiogram.[3]

Following Gastroduodenal Surgery

The serious consequences of pancreatitis complicating gastroduodenal surgery are generally well recognized, and a number of studies have been published in regard to the pathogenesis, preventive measures, and frequency of the disease in this form. This series includes 13 such cases.

The diagnosis in four was malignancy of the stomach, with three instances of carcinoma and one of lymphosarcoma. Subtotal gastrectomy was done in three, total gastrectomy in the other. The pancreas was not involved in any of these cases, the pancreatitis was mild in each instance, and all four recovered.

Subtotal gastric resection was done for benign gastric ulcer in three cases. In all three there was posterior penetration of the ulcer into the pancreas. The pancreatitis was mild in all, and two recovered without incident. The third patient died of intra-abdominal sepsis not believed to be related to the relatively mild pancreatitis.

In another group of three, operation was performed for chronic duodenal ulcer. In one a vagotomy and gastroenterostomy were performed with no duodenal dissection; the subsequent pancreatitis was mild. In the second (Case 3) a subtotal gastrectomy was performed with a very difficult dissection necessary for the duodenal mobilization because of dense adherence of the involved portion of the duodenum to the pancreas. The very severe pancreatitis in this case ended fatally. In the third case hemigastrectomy and vagotomy with a gastroduodenal anastomosis was made difficult by a similarly hazardous duodenal dissection, accomplished in this instance with the duodenum open. The resulting pancreatitis was moderate in degree with recovery of the patient after a more trying than usual postoperative course.

An emergency subtotal gastrectomy for massive hemorrhage from a marginal (gastrojejunostomy) ulcer was performed in one case. This patient died of peritonitis 11 days after operation. At autopsy the pancreatitis was only mild in degree, and hemoperitoneum and peritonitis were deemed the basic causes of death. A mild pancreatitis followed total gastrectomy for a huge neurilemmoma of the stomach. In the final instance (Case 4) pancreatitis of moderate severity followed excision of a large duodenal diverticulum. Both of the last two patients recovered.

A number of the important considerations in recognition and pathogenesis are brought out by the following case reports.

CASE 3.—A 52-year-old white man was hospitalized with a long history typical of chronic peptic ulcer. Following gastroenterostomy, performed 20 years previously, the patient had recurrent intermittent periods of abdominal pain. In the three days preceding this admission the patient passed tarry stools and noticed considerable weakness. Upper gastrointestinal radiologic examination showed a definite penetrating ulcer in the postbulbar portion of the duodenum.

Eleven days following admission a subtotal gastric resection with a Hofmeister type of anastomosis was performed. At the time of surgery the old gastroenterostomy was taken down, and a marginal ulcer at the stoma was demonstrated. In addition, there was a chronic posterior penetrating duodenal ulcer which was firmly attached in the region of the common duct. This duodenal ulcer was quite large and mobilization was difficult. The ampulla of Vater was identified within 1.5 cm. of the cut edge of the duodenum. There was some concern at the time of surgery about the security of the duodenal closure.

Postoperatively the patient complained of severe abdominal pain and ran a progressively febrile course. The serum amylase determination on the fifth postoperative day was normal, but on this same day the blood urea nitrogen determination was 88.5 mg. per 100 cc. His abdomen showed increasing signs of peritonitis with marked tenderness and rigidity, and his pulse increased to 140 on fifth postoperative day. The diagnosis of dehiscence of the duodenal stump was made, and laparotomy was again performed. The duodenal closure was found to be intact, but the pancreas showed obvious evidence of severe necrosis and hemorrhage. No procedure except for the placement of drains down to the region of the pancreas was performed. Postoperatively the patient continued to deteriorate and died the following day.

The difficulties encountered in the duodenal mobilization and closure can logically be related to the ensuing pancreatitis. Direct trauma to the head of the pancreas incident

to this dissection and removal of the ulcer is an obvious factor, although trauma of this nature to the pancreas is rarely followed by pancreatic inflammation or necrosis. Division and ligation of the accessory pancreatic duct (duct of Santorini) is a more attractive theory. The location of the duodenal opening of this duct proximal to the ampulla of Vater makes it distinctly vulnerable to damage in a dissection of this kind. Encroachment on the main pancreatic duct (duct of Wirsung) is a slighter possibility, and interference with the blood supply to the pancreas is still another possibly significant etiologic factor. Unfortunately postmortem examination was not permitted in this case, so that the anatomical relationships of the ducts and the blood vessels are not known.

CASE 4.—This 51-year-old white woman was admitted to the surgical service because of cramping right upper quadrant pain of approximately one year's duration, noticed particularly after eating a large meal or when lying flat on her back. The patient had avoided cabbage, melon, and other roughage foods for the past several years, because these seemed to increase her symptoms. An upper gastrointestinal series disclosed a very large diverticulum arising from the lateral wall of the descending loop of the duodenum. Other radiological and laboratory studies were within normal limits.

Because of the persistence of her complaints elective removal of the duodenal diverticulum was performed. When mobilized, the diverticulum was found to arise from the posterior wall of the second portion of the duodenum very close to the ampulla of Vater. An anterior duodenotomy was done, and one catheter was passed up the common duct and another passed up the main pancreatic duct. With these structures identified in this fashion, excision of the diverticulum was completed.

The day following surgery serum amylase in this patient was 969 units. The following day it dropped markedly and by the fourth postoperative day was entirely normal. On the third postoperative day there was drainage of a copious amount of fluid from the stab wound in the right flank in which a Penrose drain had been left. This was shown to be a duodenal fistula, inasmuch as dye given by mouth appeared in the drainage within a few minutes. However, by the next day the drainage had markedly diminished and completely ceased within four days. The patient's subsequent course was entirely unremarkable except for a low-grade fever persisting until the 10th postoperative day.

The most acceptable explanation for the acute pancreatitis following this procedure would seem to be temporary obstruction of the main pancreatic duct. The use of a catheter in the pancreatic duct as a safety measure during the dissection may have produced sufficient local edema and inflammation of the duct or the ampulla of Vater to produce such an obstruction. Less attractive are the possibilities of direct trauma to the head of the pancreas, which was minimal in this instance, or interference with the blood supply to the pancreas. The Kocher maneuver was used to mobilize the duodenum and the head of the pancreas and hence to facilitate the procedure, but this maneuver is used almost routinely on this service during gastroduodenal operations and is virtually bloodless. For this reason, and because mobilization of the diverticulum itself did not necessitate ligation of any significant blood vessels, the likelihood of vascular interference seems remote.

Complications Following Splenectomy

Acute pancreatitis following splenectomy is uncommon, and there were only three such cases in this series. In one patient with acquired hemolytic anemia, oliguria, azotemia, and atelectasis also developed postoperatively, terminating in the patient's death on the seventh postoperative day. In the other two a focal pancreatitis led to a left subphrenic fluid collection. In all the splenic artery was ligated in continuity early in the operation in its position over the superior portion of the tail of the pancreas proximal to the splenic hilus. In all also, the splenectomy was technically more difficult than usual, and there was definite operative trauma to the tail of the pancreas.

CASE 5.—A 57-year-old white woman was admitted to the University Hospital with a chief complaint of generalized purpura. The patient had been in good health until two days prior to admission, at which time she noticed the appearance of several various-sized bruises on her body as well as multiple small petechiae. Laboratory data

at the time of admission showed a hemoglobin of 14.4 gm. per 100 cc. and no platelets in the peripheral blood. A bone marrow preparation showed an increase in total cellularity; the megakaryocytes were increased in number and were qualitatively normal. A diagnosis of essential thrombocytopenic purpura was made.

Splenectomy was performed on the day of admission. The spleen was twice normal size, and the operation was rather difficult because of edema and induration in the retroperitoneal area. Mobilization of the spleen was complicated by laceration of the tail of the pancreas. Bleeding vessels in the tail of the pancreas were ligated with mattress sutures of fine silk. Postoperatively the patient developed a low-grade fever for seven days. A recrudescence of this fever beginning on the 13th postoperative day lasted for approximately two weeks. She had considerably more than the usual amount of postoperative ileus. Considerable abdominal distress during the first five postoperative days required narcotics for control at fairly regular intervals. Serum amylase determination on the third postoperative day was 947 units and was 1045 units on the following day. She developed mild jaundice, and a marked leucocytosis, which rose as high as 50,800 per cubic millimeter on the eighth postoperative day, indicated the severity of the inflammatory process. The serum calcium level remained normal. On the 23rd postoperative day the patient ruptured a subdiaphragmatic collection of fluid, and amylase determination on this fluid was 2035 units. A catheter was placed into the left subdiaphragmatic pocket, and constant suction for a number of days was instituted. The patient was ultimately discharged home on the 49th postoperative day with a catheter still in place in the left subdiaphragmatic space. Injection of contrast material through the indwelling catheter one month later demonstrated a large pocket in the region of the tail of the pancreas. This connected by a sinus tract to the left subphrenic area and then out through the catheter. It is apparent that an area of pancreatic necrosis developed in the tail of the pancreas. With resolution of the necrosis a cystic space formed in this area which communicated to the subphrenic space.

Direct trauma to the tail of the pancreas and interference with the local blood supply reasonably explain the pancreatitis in this case. In all probability damage to the tail of the pancreas during splenectomy oftener results in a temporary pancreatic fistula than in pancreatitis. Such a fistula commonly results in a left subphrenic collection of fluid. In this case there was evidently both a localized area of pancreatic inflammation and necrosis and a fistula with a subphrenic collection.

One isolated case in the present series followed a right colectomy for carcinoma of the hepatic flexure of the colon. The mass was adherent but did not invade the head of the pancreas. Because of direct invasion of the duodenum, a portion of the anterior and lateral aspects of the third portion of the duodenum was included with the resected colon. A severe complicating pancreatitis ended in the patients' death on the ninth postoperative day.

Comment

The significance of postoperative pancreatitis is perhaps best measured by its importance as a cause of death in biliary tract and gastroduodenal surgery (Table 2). In a recent six-year period at this hospital, 6 of 13 deaths following biliary tract operations were associated with postoperative pancreatitis. Warren has emphasized this complication as one of the commonest causes of death after gastric operations.[4] Millbourn concluded that some degree of pancreatitis follows about 10% of gastric resections, using the urinary diastase test as his diagnostic criterion in a series of 147 consecutive cases.[5] Of the 13 cases with complicating pancreatitis in his series, 5 had severe clinical symptoms and 2 of these died.

TABLE 2.—*Over-All Experience with Respect to Antecedent Surgery and Mortality*

	Postoperative Pancreatitis	
Operation	Cases	Deaths
Biliary tract	13	6
Gastroduodenal	13	3
Splenectomy	3	1
Rt. colectomy	1	1
Total	30	11

Acute pancreatitis following biliary tract surgery has received relatively little attention, although in our experience this has been a particularly lethal type. No single

factor in the procedure itself has been definitely shown to be related to a postoperative pancreatitis. All have followed common bile duct exploration, but in only a few were stones recovered. Hence it seems unlikely that preexisting disease in the common duct is a necessary factor. The technique described by Cheever has been used routinely during these explorations, passing woven silk elastic olive-tipped urethral catheters of increasing size down through the ampulla of Vater, and irrigating the distal portion of the duct on their withdrawal in an effort to flush out any calculi.[6] In those instances in which a common channel is present, this irrigating fluid in some instances must inevitably be forced up the main pancreatic duct. The resistance of the sphincter of Oddi, the anatomic arrangement of the pancreatic ducts, and the force used in the irrigation would all be factors in the amount and pressure of such retrograde flow. If the accessory duct does not communicate with the duodenum and hence cannot drain off such fluid, the combination of a tight ampulla of Vater with a common channel plus vigorous irrigation might well force fluid back up the pancreatic duct system under sufficient pressure to rupture acini. Kleitsch reports that in about 30% of persons the anatomic arrangement of the pancreatic ducts would theoretically allow such a situation.[7] It has been demonstrated experimentally many times that retrograde injection of bile into the pancreatic duct under sufficient pressure to cause extravasation into the interstitial spaces regularly produces severe pancreatitis. The effect of lower pressures is not as well standardized and depends on other factors such as stimulation of the pancreas and interference with the blood supply.

Trauma to the head of the pancreas during retroduodenal palpation of the common duct is another possible cause of pancreatitis, although the frequency with which this maneuver is practiced without apparent ill effects is good evidence against its importance. In rare instances the limb of a long T-tube which is drawn through the ampulla of Vater may obstruct the outlet of the main pancreatic duct. Such an obstruction can lead to pancreatitis, as apparently happened in one of our cases with resulting death. A similar case with a fatal result from the same mechanism has been reported by Smith and others.[8]

Schmieden and Sebening in their excellent early review found that 91 of a total of 145 collected cases of postoperative pancreatitis followed gastric operations.[9] Since that time there have been several papers on this phase of the problem, and the work of Millbourn is particularly noteworthy.[5] Not only did he present data concerning the incidence of the complication as noted previously, but he also presented some interesting evidence concerning its pathogenesis. In his series there was evidence of postoperative pancreatitis occurring four times as often following gastrectomy for duodenal ulcer as following the same procedure for either gastric ulcer or carcinoma. On the basis of this statistical evidence plus anatomic dissections of the positions of the ducts of Santorini and Wirsung, he concluded that damage to the duct of Santorini (accessory duct) must be an important factor. This duct is particularly vulnerable to injury during a difficult duodenal dissection with posterior penetration of an ulcer or with distortion of the normal anatomy from scarring. If this duct is ligated or divided and if it is the main outflow tract for pancreatic juice, as is the situation in about 10% of persons, a serious pancreatitis may result.

Attractive as Millbourn's thesis is, Warren was unable to substantiate the critical role of injury to the accessory pancreatic duct and in fact could not find any consistent etiologic pattern in his case.[4] Dunphy was impressed by the possible importance of damage to local blood vessels and consequent ischemia to a portion of the gland, particularly when combined to the added factor of trauma.[10] He also brought up the interesting possibility that an increase in the viscosity of the pancreatic juice consequent to various factors incident to a surgical pro-

cedure might add an element of obstruction, as originally proposed by Rich and Duff.[11]

Additional theoretic etiologic factors, as listed by Millbourn, include (1) mechanical injury to the pancreas, (2) stagnation of duodenal contents with possibly secondary influence on the pancreatic secretory function or with reflux of bile or duodenal contents up the pancreatic ducts, (3) spasm of the sphincter of Oddi, and (4) isolated lesions of the pancreatic duct system.

Analysis of our material, like that of Warren's, does not support Millbourn's central hypothesis or any other obvious factor. In only 5 out of these 13 cases was the duodenum the site of the pathology. In three, damage to the duct of Santorini was possible because of dissection past a posterior penetrating ulcer. In eight of the cases there was some degree of trauma to the pancreas incident to mobilization of the stomach. In one (Case 3) there was a slight possibility of encroachment on the duct of Wirsung as well as the accessory duct. Finally, in five there was no obvious factor. There seemed little probability of significant interference with the pancreatic blood supply in these cases.

Baronofsky and co-workers studied the anatomic relationship of the tail of the pancreas to the hilus of the spleen.[12] They demonstrated that in half of the dissected specimens the distance separating these structures was 0.5 cm. or less, and in many there was direct apposition. The danger of injury to the pancreas during splenectomy is obvious, particularly if a mass pedicle clamping technique is used. It is essential to visualize the tail of the pancreas in its position close to the hilus of the spleen and to avoid it during individual ligation of the hilar vessels. These same workers also demonstrated by injection studies of the splenic artery that in about one-third of the cases there is a large recurrent artery arising close to the spleen which supplies the tail of the pancreas. They infer that ligation of the splenic artery proximal to the origin of this recurrent branch may result in ischemia and necrosis of the tail of the pancreas. However, the technique of ligation in continuity of the splenic artery proximal to the hilus has been followed routinely in elective splenectomies on this service for many years with little evidence of such a phenomenon. In the three cases of pancreatitis following splenectomy, direct trauma was an obvious factor. Hence it is our feeling that interference with the blood supply by this technique is rarely if ever sufficient to cause pancreatic necrosis.

Summary

Postoperative pancreatitis ranks as a significant cause of death in upper abdominal surgery, particularly following operations on the biliary tract and stomach. Recognition of the complication on clinical criteria alone is often difficult, so that reliance on the serum amylase test in the early postoperative period is recommended.

Irrigation of the common bile duct in an effort to dislodge calculi is postulated as a reasonable mechanism of producing acute pancreatitis under anatomical circumstances which permit reflux of fluid up the main pancreatic duct under pressure.

The possible dangers of a severe pancreatitis developing as a consequence of damage to the duct of Santorini during duodenal mobilization, of direct trauma to the pancreas, or of interference with the pancreatic blood supply should be fully appreciated by those performing gastroduodenal surgery.

Safety measures to circumvent the threat of causing an acute pancreatitis merit application when a possibly hazardous operative maneuver in this connection is contemplated.

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Pseudocysts of the Pancreas

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and
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Pseudocysts of the pancreas occur infrequently. In 4329 admissions to the V. A. Hospital, Huntington, W. Va., from Jan. 1, 1952, to June 30, 1954, five patients with cysts have been operated upon. On reviewing the literature it was found that but few surgeons have had large series of cases, and most reports are made on the basis of one or two cases. There has been no uniformity of opinion as to treatment.

Classification of pancreatic cysts is well agreed upon and is based on etiology. They are usually divided into (1) congenital, (2) neoplastic, (3) retention, (4) parasitic, and (5) pseudocysts. Congenital cysts of the pancreas are rare and are usually associated with cysts of other viscera, such as liver and kidney. The term retention cysts should be used to designate cystic dilatations arising secondary to partial or complete occlusion of the pancreatic ducts. The neoplastic cysts are the cystadenomas, the cystadenocarcinomas, and, rarely, teratomas and sarcomas. These cysts are usually multilocular and have the appearance of a tumor. Parasitic cysts are seldom, if ever, seen in this country.

Pseudocysts, in contrast to true cysts of the pancreas, have no epithelial lining but are rather fluid-containing sacs with walls of fibrous tissue. This presence or absence of epithelial lining, together with the pathogenesis, is the basis of differentiation of the true from the false cysts. Should a retention cyst become exceedingly large, its lining may undergo necrosis and be histologically indistinguishable from that of a false cyst.

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Pathogenesis

The pseudocyst follows trauma to pancreas or acute pancreatitis, with and without coexistent biliary tract disease. The process of cyst formation is the same regardless of the etiologic factor. There is an outpouring and activation of pancreatic enzymes, trypsinogin and lipase. When these rupture into the lesser omental sac, there is an intense localized inflammatory reaction. The foramen of Winslow is sealed off, and the exudate is encapsulated by the proliferation of a fibrous capsule. The shape of the newly formed cyst will be determined by the structures bounding the lesser peritoneal cavity. It may even extend upward into the chest or downward retroperitoneally.

Diagnosis

Diagnosis of a pancreatic cyst is made primarily by x-ray. The displacement of the stomach, colon, and occasionally kidney by a smooth round upper abdominal mass makes a tentative diagnosis. A history of trauma to the pancreas or pancreatitis, acute or chronic, helps substantiate this opinion. The palpation of a smooth round mass, frequently asymptomatic, further corroborates it. Only at surgery can the true nature of the cyst be determined. Histologic sections are necessary for definite diagnosis.

Treatment

The surgical approach to pseudocysts has not been consistent. It can be divided into (1) excision and (2) drainage. The forms of drainage may be further divided into

internal and external. Surgical treatment may be summarized as follows:

1. Excision
2. Drainage
   (*a*) External
      (1) Marsupialization
      (2) Catheter
   (*b*) Internal
      (1) Cystogastrostomy
      (2) Cystojejunostomy
      (3) Cystocholecystostomy
      (4) Cystoduodenostomy

Suffice it to say that the magnitude of surgery about the pancreas limits the excision of cysts to the smallest of cysts and to those located at or near the tail of the pancreas. However, credit for removal of the first cyst goes to Bosemann, who in 1882 extirpated a cyst weighing 20.5 lb.

Drainage in the form of marsupialization was first employed by Gussenbauer, in 1883. External drainage in this manner, and by means of a catheter sutured to the inside of the cyst, remains the most popular surgical treatment to this day.

Internal drainage has been carried out by anastomosis of the cyst to the gall bladder, duodenum, stomach, and jejunum. The Roux-en-Y type of cystojejunostomy has been favored recently, as has a (transgastric) cystogastrostomy.

There are recent reports of drainage of the cyst by sphincterotomy when the cyst communicates with one of the larger pancreatic ducts.

CASE 1.—A 38-year-old white man was admitted to the V. A. Hospital, Huntington, W. Va., March 20, 1952, with a diagnosis of internal hemorrhoids. He stated that he had had rectal bleeding from hemorrhoids for the previous two years and had lost 30 lb. during the previous year. He had used alcohol to excess for many years.

Physical examination revealed an undernourished man. Deeply situated in the left upper quadrant of the abdomen was a smooth mass which was firm and nontender, and moved slightly on inspiration.

Results of laboratory examinations were within normal limits.

X-rays of the large bowel were negative. Calcifications in the region of the head of the pancreas were seen incidentally and were interpreted as pancreatic calculi. Gastrointestinal series showed the stomach to be displaced to the right by a large mass. Chest x-ray and cholecystograms were normal.

Exploratory laparotomy was carried out on April 3, 1952. When the peritoneal cavity was entered, a massive cyst was encountered lying behind the stomach, pushing the stomach and transverse colon anteriorly. The gastrocolic ligament was divided. The cyst was opened, and approximately 1500 cc. of yellowish cloudy fluid was aspirated. Biopsy of the cyst wall showed it to be compatible with a pseudocyst. Marsupialization was carried out by anchoring the cyst to consecutive layers of the abdominal wall with the mouth of the cyst projecting about 1 cm. beyond the skin edges. A drain was kept in the cyst for several weeks postoperatively, and though the drainage was profuse for a few days it had nearly ceased one month postoperatively. Minimal drainage persisted for six months. Approximately one year later, gastrointestinal series showed a filling defect on the greater curvature side of the stomach. At laparotomy this was found to be the fibrous remnant of the patient's drainage tract. It was

Fig. 1 (Case 1).—Oblique view showing stomach's forward displacement and pressure in its midportion; March 28, 1952.

Fig. 2 (Case 1).—Deformity of greater curvature produced by extrinsic pressure from remaining fibrous tract after drainage had ceased; March 20, 1953.

Fig. 3 (Case 1).—Lateral view of stomach one year after drainage of cyst and three weeks after excision of residual fibrous drainage tract; April 17, 1953.

excised. The patient was having no difficulty at this time. He has since developed diabetes, which is controlled.

Case 2.—A 31-year-old Negro man was admitted to the hospital on Oct. 20, 1952, with a complaint of cramps in the abdomen, of two days' duration. He had vomited repeatedly, and his distress had become progressively severer until the time of admission. He admitted drinking heavily for the week prior to admission.

Physical examination on admission revealed a temperature of 99 F; pulse rate, 120, and blood pressure, 90/70. The patient was acutely ill. Lungs were normal at the time of admission, but shortly afterwards there was dullness over the bases. The heart was normal except for hypotension. The abdomen was slightly distended. There was tenderness to palpation throughout with board-like rigidity in the epigastrium. Peristalsis was absent. No definite mass could be felt.

Red blood cell count was 5,700,000, and hemoglobin, 19 gm. per 100 cc. White blood cell count was 14,100. Serum amylase was 36 mg. per 100 cc. Chest film on admission was negative except for an elevated diaphragm. The following day a chest film revealed fluid in the left costophrenic sinus. On the seventh hospital day there was a marked left pleural effusion with pneumonitis in both lower lung fields.

The patient was treated conservatively after admission to the hospital. On Nov. 1, 1952, a mass was palpated in the epigastrium, which was explored through a small upper right rectus incision. When the peritoneal cavity was entered, obvious fat necrosis was seen and there was an accumulation of fluid behind the stomach. A Foley catheter was placed down to the site of accumulation of fluid, and the wound was closed in layers. Amylase activity of this cystic fluid was reported as 1158 mg. per 100 cc. The patient did well postoperatively. Chest film on Dec. 4, 1952, revealed pleural effusion on the left, and approximately 900 cc. of clear fluid was withdrawn from the left pleural space. Culture of the fluid was negative. Drainage from the cyst continued for approximately six months. After cessation of the drainage, the patient had no difficulty. Gall bladder series was carried out on the patient just prior to discharge, and it showed a small gall

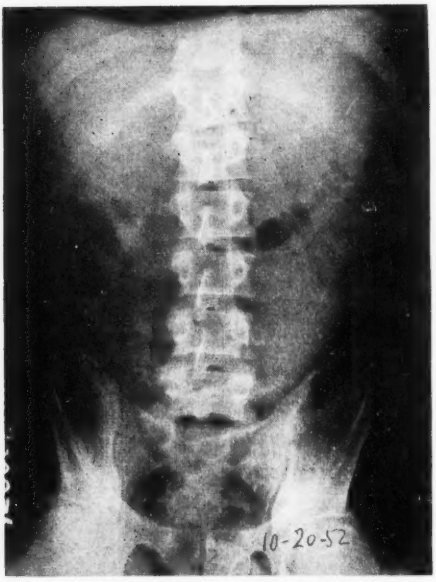

Fig. 4 (Case 2).—Plain film of abdomen showing vague outline of massive intra-abdominal cyst; Oct. 20, 1952.

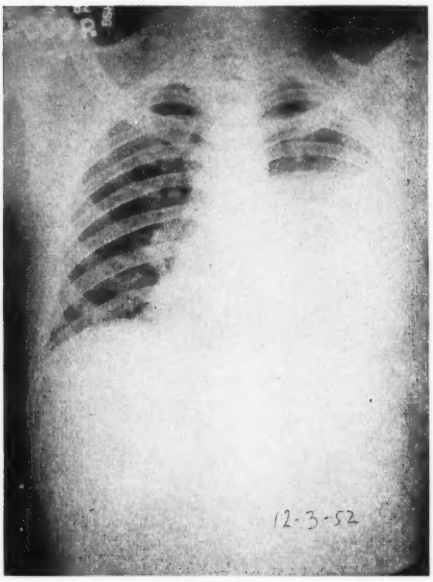

Fig. 5 (Case 2).—Pleural effusion, left chest, associated with acute pancreatitis; 900 cc. of sterile fluid was withdrawn; Dec. 3, 1952.

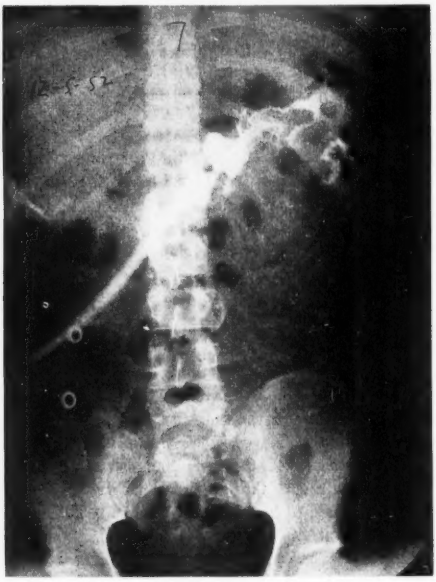

Fig. 6 (Case 2).—Iodized oil instillation into remnants of pancreatic cyst approximately one month after drainage; Dec. 6, 1952.

bladder with good concentration and contraction. No calculi were seen.

Case 3.—A 43-year-old white man was admitted to the hospital on Jan. 28, 1954, with the diagnosis of chronic recurrent pancreatitis. He had had periodic attacks of acute pain in the epigastrium since 1943. They had increased in frequency in the past 6 months, occurring at 7- to 10-day intervals. The patient had no other symptoms. His weight had dropped from 215 to 159 lb. On Aug. 28, 1953, he had had an exploratory abdominal operation. At operation acute pancreatitis was found.

Physical examination was negative except for an old healed right upper abdominal scar.

The results of laboratory examinations were normal. Gastrointestinal series showed evidence of a tumor mass, possibly extrinsic, involving the wall of the stomach. The tumor mass also encroached upon the second and third portion of the duodenum.

Because of the diagnosis and recurrent attacks of abdominal pain, exploratory laparotomy was carried out on March 1, 1954. A large pancreatic cyst was encountered, and approximately 1000 cc. of grayish fluid, with a marked amount of necrotic material, was aspirated. The entire cyst cavity was explored, and no pockets were encountered. It was drained by placing two Foley catheters in the crater, one towards the head of the pancreas and one toward the tail. Amylase activity of the cyst fluid was reported as 214 mg.

per 100 cc. Postoperatively the patient had complete subsidence of pain. Initially there was a marked amount of drainage, approximately 250 cc. daily. One month later the amount of drainage was down to about 1 oz. (30 cc.) daily. The diminution of size of the cyst was observed about every six weeks by the instillation of iodized oil U.S.P. (Lipiodol) into the cyst through the catheter. The patient was discharged on Sept. 1, 1954, at which time the drainage amounted to about 1 oz. daily. He returned to the hospital because of continued drainage, and on March 17, 1955, the sinus tract was implanted into the posterior wall of the stomach. The patient has been asymptomatic since.

Fig. 7 (Case 3).—Film showing displacement of stomach upward and thinning of barium in midstomach, due to extrinsic pressure; Feb. 5, 1954.

CASE 4.—A 27-year-old white man transferred to the hospital on Sept. 18, 1953. Three months previously the patient was in an automobile accident, sustaining a concussion of the brain and multiple rib fractures. He remained comatose, and a tracheotomy was performed in the hospital where he was first treated. On transfer to this hospital the tracheotomy tube was in place and the patient was fed through a Levin tube. He was irrational and required continual restraint.

Physical examination at the time of admission revealed an emaciated irrational white man. There was a severe rectal prolapse and a decubitus ulcer of the left hip. Examination was otherwise negative.

Results of laboratory examinations were within normal limits.

The patient was given supportive therapy. Three days after admission the tracheotomy tube was removed, and approximately two months later he began to talk and eat. On Jan. 12, 1954, the patient's ward doctor noticed that there was a mass in the upper portion of the abdomen. The mass

Fig. 8 (Case 3).—Iodized oil, visualization of remnants of pancreatic cyst after catheter drainage; March 26, 1954.

was nontender and produced no symptoms. Gastrointestinal series revealed the stomach to be riding on a large round mass which occupied the entire midabdomen. The stomach was displaced upward and to the right. Inasmuch as the mass was giving the patient no difficulty, surgery was deferred. On May 10, 1954, exploratory laparotomy was carried out. When the abdomen was entered, the stomach was found to be compressed against the

Fig. 9 (Case 3).—Catheter in sinus tract, one year postoperatively, showing depth and position of persistent fistula; March 16, 1955.

anterior abdominal wall. The gastrocolic omentum was opened, and a pancreatic cyst was found which was densely adherent to the posterior wall of the stomach. The cyst was opened for a distance of approximately 2 in., and approximately 2000 cc. of contents was aspirated. These contents were grayish. Anastomosis between the cyst and the stomach was carried out. The patient was treated postoperatively with gastric suction for five days and thereafter with a progressive Sippy type of diet. He had no particular distress. Eleven days postoperatively gastroscopy was done and the area of the cystogastrostomy was found. There was apparently complete healing, as the anastomosis could not be opened. Gastrointestinal series at this time revealed that the stomach had returned to normal position and was normal in size. No barium entered into the pancreatic cyst. To date there has been no sign of recurrence of the cyst.

CASE 5.—A 33-year-old white man was first admitted to the V.A. Hospital, Huntington, W. Va., on Jan. 22, 1954. He gave a history of having developed pain in his upper abdomen on Dec. 22, 1953, at which time he vomited several times. Gastrointestinal tract x-rays carried out here were normal. A cholecystogram showed nonvisualization of the gall bladder. White blood cell count was 12,100. Other routine laboratory work was within normal limits. The patient had epigastric pain intermittently while hospitalized, and he was treated symptomatically and was discharged. He reentered the hospital on March 20, 1954, stating that three days previously he had noticed black tarry stools. These had continued up until the day of admission. On the day prior to admission he vomited some dark blood and had moderately severe epigastric distress.

Physical examination at this time revealed a marked pallor. The patient was acutely ill. The heart and lungs were normal except for a pulse rate of 120. There was generalized tenderness in the abdomen, more marked in the upper half.

Laboratory studies revealed 19,800 white blood cell count. Red blood cell count was 1,170,000, with hemoglobin 3 gm. per 100 cc. and hematocrit value 11 vol.%. Serum amylase was 56 mg. per 100 cc.

In view of the patient's past history, it was assumed that he had a peptic ulcer which was bleeding, and on March 23, 1954, after blood was given, an exploratory laparotomy was carried out. An exceedingly large pancreatic cyst was encountered, with an acute inflammatory reaction involving the gastrohepatic omentum in the area about the distal portion of the stomach and the entire porta hepatis. The gall bladder was inflamed and filled with stones. As the initial procedure the gall bladder was removed and the common duct was cannulated through the cystic duct with a small urethral catheter. Secondarily, the pancreatic cyst was opened and approximately 1000 cc. of grayish fluid was removed. The cyst was thoroughly explored, and no smaller areas or pockets were found. Anastomosis between the cyst and the posterior wall of the stomach was carried out because of the proximity of the two. No stones were palpated in the common duct, and, because of the extreme vascularity of surrounding tissues, the common duct was not opened. The catheter was left in the common duct and was brought out through the wound. Biopsy of the cyst was reported as pseudocyst of the pancreas. Amylase activity was reported as 283 mg. per 100 cc. There was no gastric or duodenal ulcer. Postoperatively, he had symptoms which would be commensurate with a penetrating ulcer. These, however, were controlled with propantheline (Pro-Banthine). Bile drainage through the catheter ceased in about 12 days, and at the end of 2 weeks the catheter was removed. Before the catheter was removed a cholangiogram was performed, showing a normal biliary tree. At the end of three weeks gastrointestinal series showed on the lesser curvature

Fig. 10 (Case 4).—Plain film of abdomen outlining an intra-abdominal mass; Oct. 21, 1953.

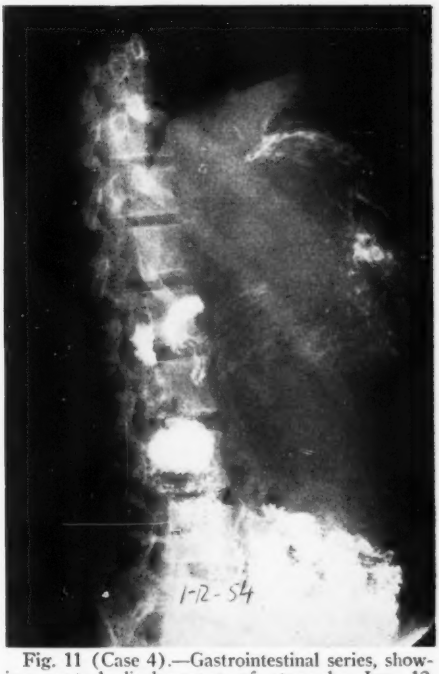

Fig. 11 (Case 4).—Gastrointestinal series, showing ventral displacement of stomach; Jan. 12, 1954.

Fig. 12 (Case 5).—Anteroposterior view of stomach showing displacement due to an extrinsic mass high in the abdomen; Jan. 26, 1954.

Fig. 13 (Case 5).—Anteroposterior view of stomach after cystogastrostomy. Antral defect, site of anastomosis, is visible; April 27, 1954.

side of the stomach an irregular outline which was interpreted to be a residual of the pancreatic cyst. The patient has been followed since and to date has had no return of his symptoms.

Comment

In the first patient operated on, the cyst was marsupialized. Drainage persisted for about six months, and the patient was incapacitated for lack of a suitable method of collecting the pancreatic juice. The next two cases were drained externally with use of Foley catheters with daily irrigation of the cyst space. These patients could control leakage about the catheters by rubber band traction, but the necessity for wearing a bottle to collect the secretion and the 4- to 12-month period of drainage were undesirable. One patient required a secondary operation to remove the sinus tract. In none of these patients was excoriation of the skin about the drainage site a problem, though the amylase activity remained high in all until drainage ceased. In the last two patients the cyst was anastomosed to the posterior wall of the stomach. The anastomosis was done through the gastrocolic ligament. The cyst was opened longitudinally for about 4 cm., and a corresponding opening was made through the posterior wall of the stomach. The cyst was thoroughly explored, adequate biopsy specimens were taken, and a two-layer closure was carried out. A Levin tube previously put down into the stomach was directed into the cyst through the cystogastrostomy. In one of the patients adherence of the cyst to the stomach wall obviated the posterior suture row. After surgery the patients complained of ulcer type pain which was controlled by propantheline. These patients were followed both by gastroscopy and by gastric fluoroscopy. On the 11th postoperative day the anastomosis scar was easily visible and was clean but could not be opened with air introduced into the stomach through the gastroscope. Gastrointestinal series done six weeks postoperatively showed the stomach and colon to be in their normal position, with a small ulcer-like defect in the posterior wall of the stomach, being the only residual of the cyst. In neither of the two cysts drained by cystogastrostomy was there any tendency for the barium to fill the cyst. It was felt that the cyst space had been obliterated rapidly and healing had taken place as it does with a perforated gastric ulcer. This last type of drainage is advocated because of the speed of convalescence. It has none of the disadvantages of the continual irrigation and dressings needed for several months with external drainage. Neither does it interrupt bowel continuity, and the anastomosis is carried out in the lesser peritoneal cavity, where chances of later complications, as adhesions and bowel obstruction, are lessened.

Summary

Pseudocysts of the pancreas are uncommon. On the basis of etiology, the preceding five cases can be divided as follows: following acute alcoholic pancreatitis, two cases; following acute pancreatitis with concurrent gall bladder disease, one case; following chronic pancreatitis, one case, and following trauma to pancreas, one case.

The gall bladder and common duct were normal grossly and roentgenographically in all but the one case. The one patient with chronic pancreatitis has since developed pancreatic lithiasis and diabetes. He is pain-free.

External drainage of three cysts was a protracted procedure, with drainage persisting 4 to 12 months. The patients' chief complaint was their inability to obtain employment while the drainage persisted, though otherwise they were symptom-free. Two patients required a secondary operation to remove the persistent sinus tract.

The two patients with cysts drained internally had short smooth convalescences. The stomach seems to be the logical site for drainage because of proximity and ease of anastomosis. Fears of food entering the cysts were unfounded because of rapid obliteration of cyst space and healing of the residual defect in approximately two weeks.

DISCUSSION

ON PAPERS BY FLOYD, CHRISTOPHERSEN, AND NOER; BOLES, AND BRADLEY AND KLEIN

DR. JACOB K. BERMAN, Indianapolis: Dr. Floyd visited us when we were attempting to produce gradual vascular occlusions. He observed that we were able to occlude every major vessel in a dog successfully with a surviving animal, if the obliteration was done in a leisurely manner. In this experiment we were able to demonstrate three types of collateral circulation, depending on the site of the occlusion and the condition of the vessel peripheral to the obstruction. These we called bypass shunts, collateral anastomoses, and collateral bed types of circulation. The paper reporting this material is now in press and will appear soon in *Surgery*.

Dr. Floyd astutely observed that some of these occluding methods might be used on ducts, which, of course, do not produce collaterals, and that he could in this way reproduce the clinical counterpart of diseases caused by slow progressive obstructions of the ducts.

He has certainly shown by his experiments that chronic pancreatitis is the result of a progressive, and ultimately complete, obstruction of the pancreatic duct, albeit we do not know the cause of the obstruction. By producing the disease in an experimental animal, he will no doubt lead us to a more rational approach to its proper treatment.

His findings illustrate that which I have always referred to as Cohnheim's laws of occlusion. They are clearly exemplified in ureteral obstructions. If the block is sudden and complete, there will be atrophy of the organ. This is understandable because the intraductal pressure reaches a point where it equals venous pressure, causing an interference with venous outflow. Arterial blood enters while venous pressure mounts, giving rise to stasis, local anoxia, necrosis, and ultimate fibrosis. If the imperforation is incomplete, there will be hypertrophy, whereas if it is intermittently complete there will be dilatation of the kidney pelvis and calyces with pyonephrosis. Gradual progressive occlusion causes distention of the kidney pelvis and calyces, cyst formation, and hydronephrosis. These sequences are noted when the ducts of the salivary glands, liver, and pancreas are narrowed or obstructed, the same as they are in the kidney.

Reflux is probably not the cause of the pancreatic changes but may play a role in the causation of ductal obstruction.

Dr. Boles' discussion of postoperative pancreatitis is timely. At the risk of being called an iconoclast, I must confess, as I did in one of my weekly conferences in the Indianapolis General Hospital about three weeks ago, that I have never used a T-tube in the common duct, preferring a soft rubber catheter directed toward the liver. This is usually removed in 8 to 10 days. I believe that any foreign body in the common duct for a prolonged period of time invites complications. Therefore, I have even abandoned the use of small catheters left in the duct and protruding into the duodenum in anastomoses, for the correction of congenital atresia of the common duct. I prefer instead to make the anastomosis over the catheter and then remove it through a duodenotomy.

DR. E. LEE STROHL, Chicago: Experimental studies have shown that simple obstruction of the pancreatic duct will not produce acute hemorrhagic pancreatitis. The obstruction must occur during digestion, when there is present an active pancreatic enzyme of high trypsinogen value. Associated with the obstruction, some form of trauma or interference with pancreatic blood supply must have occured. The trauma may be due to rupture of the small pancreatic ducts from bile under pressure, localized thrombosis or thrombophlebitis, or injury of the pancreatic blood supply. The forms of trauma to the duct of Wirsung include: (1) edema or hemorrhage following instrumental exploration of the distal common duct; (2) damage to the pancreatic duct, or duct of Santorini, by ligation or angulation; (3) pressure from a long-arm tube which has been passed down the distal common duct through the papilla and into the duodenum.

At the 1955 meeting of the Western Surgical Association in Seattle, we presented a paper dealing with four patients who developed acute hemorrhagic pancreatitis in the early postoperative period. Each patient had common duct exploration, removal of stones, and drainage of the distal common duct with a long-arm tube. The findings were confirmed at autopsy in each instance.

In 1911, McArthur presented the two-catheter method of drainage of the common duct. Before the days of safe parenteral fluids, this method had a great advantage for the much needed administration of fluids, bile, and nourishment. In 1946, Cattell developed the long-arm T-tube, the principle of which is essentially that of the two-catheter method of McArthur.

We carried out fresh tissue dissections of the terminations of the common bile and pancreatic ducts. A thin septum between the bile and pancreatic ducts can usually be demonstrated, whether or not the ducts open separately into the duodenum or open into a common channel a few millimeters above the papilla. Furthermore, we found the average diameter of the common bile duct at the papilla to be 3 mm.

A tube passing through the distal common duct and papilla may occlude, partially or completely,

the pancreatic duct by pressure on the thin septum. Associated trauma from instruments and manipulation increases the chances of possible obstruction.

Long-arm T-tubes are manufactured in sizes 6 F. to 36 F., or 2 mm. to 12 mm., since the conversion factor from French to millimeter is 3. Therefore, when the usual long-arm tube of 14 F. to 16 F. is inserted through the papilla, partial or complete obstruction of the pancreatic duct is produced, and complete obstruction results at the papilla.

In 36% of the patients the ducts of Wirsung and Santorini are connected. In 10% of the patients the duct of Santorini is the major pancreatic duct. In a patient with either of these anatomical situations, obstructions of the duct of Wirsung would produce no back-pressure of pancreatic secretions. It follows, on a statistical basis, that long-arm tubes may be safe in approximately 60% of patients. At operation, however, one is unable to determine with certainty which pancreatic duct is the dominant duct.

We suggest that if one elects to use a long-arm tube the distal limb projecting through the papilla should not exceed size 6 F. to 8 F., to prevent obstruction of the duct of Wirsung. In our opinion, obstruction of the distal pancreatic duct by a long-arm tube is a factor in the production of acute hemorrhagic pancreatitis in certain patients.

DR. STANLEY HOERR, Cleveland: I should like to add a comment to Dr. Boles' paper, and to state that my own personal experience has been almost identical with what he has reported in every respect; namely, that acute, severe pancreatitis, usually hemorrhagic, accounts for approximately half of the fatalities in surgery of the bile ducts and the stomach, that it is an unpredictable complication, and that, at least in my own experience, a careful autopsy frequently does not disclose the source of the difficulty.

I am in a position to report a small series of cases of my own. They were unusual and dramatic enough so that it is very easy to remember them. One of two deaths that I had in approximately ninety gastric resections for duodenal ulcer was due to hemorrhagic pancreatitis. The patient had a penetrating ulcer of the duodenum and a rather difficult resection. I expected that the cause would be related to the turned-in duodenal stump, but at autopsy it was disclosed that the pancreatitis had, singularly enough, left that portion of the pancreas alone, and it was in the body and the tail.

Two patients developed fatal hemorrhagic pancreatitis in a series of about four hundred patients having biliary tract surgery. Since we use routine operative cholangiography and since the incidence of this complication is about the same as that in Dr. Boles' series, it is difficult for us to implicate cholangiography as a cause.

In one of the two cases removal of common duct stones had to be carried out through the duodenum, and it was obvious that trauma was a precipitating factor. At autopsy, however, the pancreatic duct was demonstrated to be wide open; so obstruction of the duct was certainly not a factor.

The other case, a jaundiced woman, had a relatively easy removal of common duct stones. Nevertheless, she developed a fatal hemorrhagic pancreatitis, and the cause for it could not be clearly demonstrated at postmortem examination.

The only death occurring in a rather lucky series of over 100 gastric resections for gastric ulcer has also been from a suppurative pancreatitis, in an elderly man who had a large penetrating gastric ulcer that involved both the pancreas and the liver. He died about 10 days later, undoubtedly owing to the trauma of the operation and manipulation of the pancreas in a poor-risk patient.

The only observation that I have made on these persons (and it would interest me to know what other surgeons find) is that the pancreas, with the single exception of the pancreas in the last patient, has been normal at the time of operation. I rather suspect that if there is chronic pancreatitis present a fatal hemorrhagic pancreatitis cannot develop because the secretions will be walled off within the pancreas itself.

Ruptured Aneurysm of Abdominal Aorta in an Eighty-Five-Year-Old Man

Successful Resection and Replacement by Orlon Prosthesis

J. HERMAN MAHAFFEY, M.D., Louisville, Ky.

Abdominal aortic aneurysm usually results in death from rupture of the aneurysm. The life expectancy for persons with abdominal aortic aneurysm is considerably less than that of the normal population of the same age group.[4] The onset of symptoms is generally considered to be a poor prognostic sign. Approximately 50% of these patients will die within six months to two years after the onset of symptoms.* In one series of cases the survival rate for those who were asymptomatic at the time of diagnosis was no better than the survival rate of those who had symptoms.[4] When the cause of death could be determined, 63.3% (31 of 49 patients) in Estes' series [4] and 81.6% (31 of 38 patients) in Kampmeier's group [7] died from rupture of the aneurysm. Without surgical intervention, following perforation of an abdominal aortic aneurysm, the mortality rate approaches 100%. Although death after perforation may be sudden, a period of from several hours to several days generally elapses before death ensues. Gerbode,[5] Cooley and DeBakey,[2] and others † have pointed out that prompt and early surgical intervention, resection of the ruptured aneurysm and restoration of continuity with an aortic homogratt, can convert a hopeless prognosis into a relatively more favorable one.

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From the Department of Surgery, the University of Louisville School of Medicine, and the Louisville General Hospital.

* References 1, 4, 7, 9, and 10.

† References 6 and 11.

Although arteriosclerotic aneurysms of the abdominal aorta as a rule occur in patients after the fifth decade of life, we have found no reports of successful resection of an abdominal aortic aneurysm in a patient in the ninth decade of life. The increasing age of our population and the increasing incidence of abdominal aortic aneurysms [8] make it seem desirable to report the following case of a ruptured arteriosclerotic aneurysm, with successful resection, in an 85-year-old man. Continuity was restored by the insertion of an Orlon prosthesis, and the man is still living four months after the operation.

Report of a Case

An 85-year-old Negro man was admitted to the Louisville General Hospital on Sept. 8, 1955, with the complaint of sudden, severe pain in his lower back, particularly on the left, of 90 minutes' duration. While waiting for supper, he had experienced this excruciating pain, which caused him to keep moving about in an effort to obtain relief. Three years previously, his physician had told him that he had an aneurysm of his abdominal aorta; consequently, the patient and his family were prepared for the eventuality of rupture of the aneurysm. During the interim he had experienced no difficulty which could be attributed to the aneurysm, except for inability to tolerate pressure on his abdomen or to have his belt buckled too tightly. Except for occasional puffiness of the ankles, his past history was not remarkable.

Physical examination revealed a well-developed 85-year-old Negro man in surprisingly good general physical condition. Although conscious and rational, he was uncooperative because of the pain, and he continually was thrashing about on the examining table, assuming new positions, in search of relief from his pain. The pulse rate was 96 per minute; respirations

were shallow and at the rate of 30 per minute, and his blood pressure was 90/50 mm. of Hg. There was tenderness to palpation over the abdomen and the lumbar region of the back. A large, pulsating mass was both visible and palpable in the left side of the abdomen. All of the pulses in the lower extremities were present. The hemoglobin was reported to be 10.1 gm. per 100 cc., and the white blood count was 22,600 cells per cubic millimeter. An anteroposterior roentgenogram of the abdomen (Fig. 1) revealed a large spherical mass, approximately 15 cm. in diameter, enclosed in a calcific shadow. The mass protruded to the left of the midline.

Fig. 1.—Anteroposterior roentgenogram of the abdomen. A large spherical mass, approximately 15 cm. in diameter, enclosed in a calcific shadow, is shown.

Approximately seven hours after the onset of pain, laparotomy was performed under general anesthesia. The peritoneal cavity contained approximately 150 cc. of blood-tinged fluid. The aneurysm extended from just below the renal arteries down to and including the bifurcation of the aorta (Fig. 2). A large retroperitoneal hematoma surrounded the abdominal aortic aneurysm. The perforation was on the right posteriorly against the body of one of the lumbar vertebra. Difficulty was encountered in mobilizing the aorta proximal to the aneurysm, which extended almost to the renal vessels, and as the mobilizing proceeded, considerable hemorrhage occurred from the perforation in the aneurysm. Later, further bleeding occurred when the left common iliac vein was torn as the aneurysm was freed from the inferior vena cava and left common iliac vein. After the aneurysm had been resected, the defect in the aorta was bridged with a knitted Orlon bifurcation prosthesis (Fig. 3).‡ Total blood replacement was 5 liters. The microscopic diagnosis of the excised specimen was arteriosclerotic saccular aneurysm with organized mural thrombi.

Postoperatively, the urinary output was adequate. The blood nonprotein nitrogen, which was 61 mg. per 100 cc. on the second postoperative day, gradually returned to normal. He was inadvertently ambulated on the first postoperative day, but thereafter he was kept flat

‡ The Orlon prosthesis was one of those constructed at the North Carolina State Textile School at the instigation of Dr. Paul Sanger.

Fig. 2A.—The peritoneum covering the perforated abdominal aortic aneurysm is partially reflected. Extravasated blood beneath the unreflected peritoneum is easily seen.

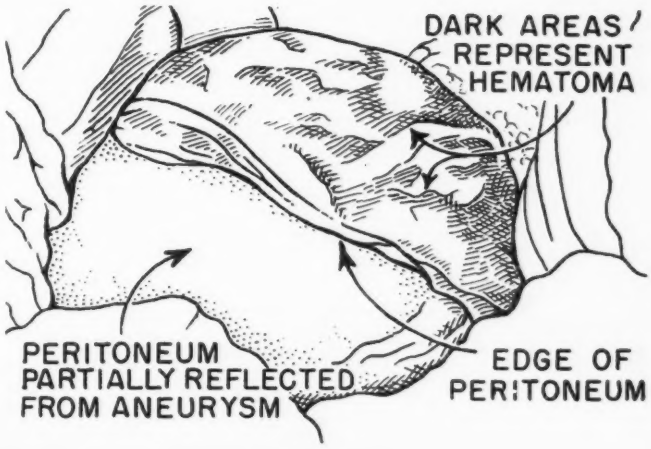

Fig. 2B.—Drawing of operative photograph (Fig. 2A) to demonstrate more clearly the retroperitoneal hemorrhage, as represented by shaded areas.

Fig. 3.—The bifurcation Orlon prosthesis is shown sutured in place following resection of the ruptured aneurysm.

in bed until the fourth postoperative day, when he was sat up. Two days later, he was ambulated. The incision healed primarily. The patient was discharged from the hospital, in good condition, on Sept. 27, 1955, eighteen days after operation. Follow-up examination on Jan. 6, 1956, revealed the patient's condition to be excellent.

Comment

The age of the patient, the amount of physical activity until time of rupture of the aneurysm, the degree of generalized arteriosclerosis, and the duration of perforation of the aneurysm before resection are important factors influencing the recovery rate.[2] Using the limited number of cases (17) whose clinical courses have been described in detail (Cooley and DeBakey,[2] six cases; Javid and associates,[6] four cases; Shumacker and King,[11] six cases, and the author's case), it is noted that no deaths occurred in the five patients who were 60 years of age or less and whose perforations, as dated from the onset of symptoms until definitive surgery was performed, varied from six hours to seven days. Seven of the nine patients in the seventh decade of life whose aneurysms perforated died. Five of these had symptoms suggesting that rupture occurred within 24 hours prior to oper-

ation. In the two patients of this group who survived, the aneurysms apparently perforated 9 and 16 days prior to surgery. One patient, age 78, whose symptoms existed 12 hours prior to surgery, subsequently died. Two patients, ages 75 and 85, whose acute symptoms began 14 days and 7 hours before operation, survived.

Shumacker and King [11] recently collected 35 surgically treated cases of ruptured abdominal aortic aneurysms, their mortality rate being 40%. Cooley and DeBakey,[3] whose experience is the largest, recently reported 22 cases of ruptured abdominal aortic aneurysms, treated by aortic resection and homografting, with a 40% mortality.

The case here reported is of particular interest because of the patient's advanced age at the time of rupture. A biologic age considerably less than his given age and the relatively early operation (seven hours after perforation) must have been important factors in the successful outcome.

Summary

A case is reported of an 85-year-old Negro man who is still living four months following resection of a ruptured arteriosclerotic aneurysm of the abdominal aorta, with restoration of continuity by insertion of an Orlon bifurcation prosthesis.

ADDENDUM

Anteroposterior and lateral roentgenograms of the abdomen obtained on May 26, 1956, revealed no calcification on mass in the region of the Orlon prosthesis. Now 86 years old, he was last seen on Sept. 6, 1956, and was in excellent condition.

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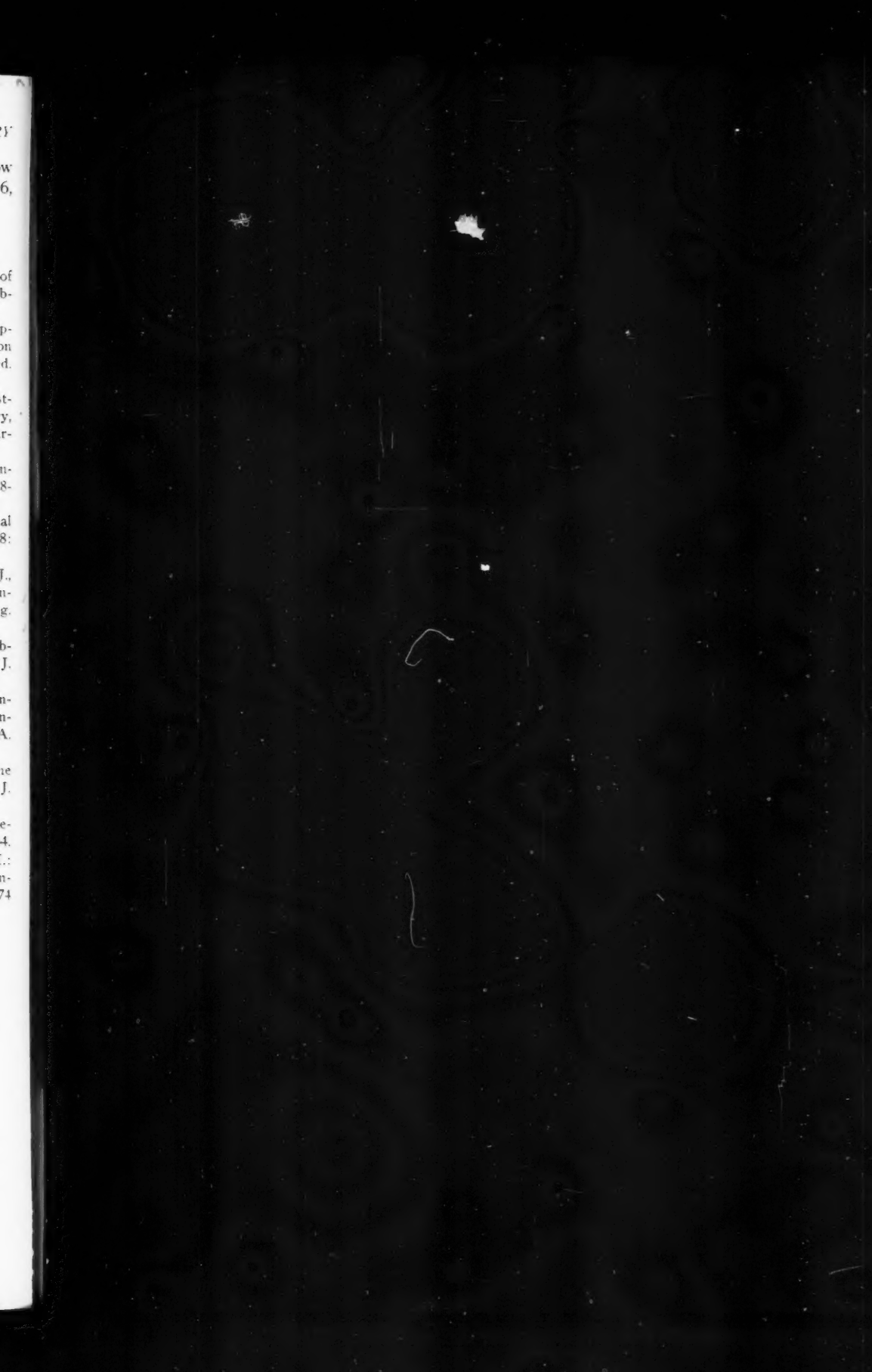
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